BOUVIER'S

FAMILIAR ASTRONOMY;

OR, AN

Introduction to the Study of the Heavens.

ILLUSTRATED BY CELESTIAL MAPS AND UPWARDS OF TWO HUNDRED FINELY EXECUTED ENGRAVINGS.

TO WHICH IS ADDED

A TREATISE ON THE GLOBES,

AND A COMPREHENSIVE ASTRONOMICAL DICTIONARY.

For the use of Schools, Families, and Private Students.

By HANNAH M. BOUVIER. Peirson

"Lift up your eyes on high, and behold who hath created these things."

PHILADELPHIA:
SOWER, BARNES & POTTS.
37 North Third Street.
1855

STEREOTYPED BY L. JOHNSON & CO.
PHILADELPHIA.

COLLINS, PRINTER.

With the warmest filial affection, this Volume is dedicated to the Memory of my Father,

John Bouvier,

to whose unremitted solicitude and parental instruction is due any merit this Work may possess.

That it may be as unerring a Guide to the young Astronomer as his Works have proved to the Legal Student, is the highest aspiration of

The Author.

NOTE.

At the solicitation of numerous Teachers, and others interested in the cause of Education, the Publishers have been induced to issue the present cheap edition of this work, which is adapted to the wants of Common Schools.

The references to Practical Astronomy, Problems, Maps, History of Astronomy, Notes, Dictionary of Astronomy, and Tables, refer to the large, complete, and elegantly printed edition, which will be found indispensable in the prosecution of this delightful study. Published in one large octavo volume, 500 *pages, substantially bound.* PRICE, $2.00.

PHILADELPHIA, 1858.

PREFACE.

This work, embracing all the recent observations of the heavenly bodies, is intended to be a complete treatise on Astronomy, conducting the pupil, step by step, from the base to the summit of the structure; explaining as far as practicable, by figures and diagrams, all the celestial phenomena, and the laws by which they are governed, without entering into those mathematical details which properly belong to treatises designed for those who propose to make Astronomy their chief study.

This science, formerly but little taught in seminaries, now claims the attention of all enlightened teachers; its importance having been acknowledged by the greatest men of all ages.

Besides elevating the mind and improving the thinking faculties, it is of the utmost utility to man. Without Astronomy we could have no proper computation of time, no true knowledge of geography, and no correspondence between distant nations; for, as Lacaille observes, "Astronomy is the governor of the civil division of time, the soul of chronology and geography, and the only guide of the navigator."

The present work is divided into five parts: the first treats of the laws which govern the heavenly bodies; the second, of the components of the solar system, and the phenomena attending their movements; the third, of the sidereal heavens, embracing the fixed stars, clusters, and nebulæ; the fourth, of the principal instruments used in the observatory; and the fifth, of the use of the globes. To which is appended two celestial maps and a comprehensive Astronomical Dictionary, which

will facilitate the studies of the pupil, and relieve the teacher from much explanation which would otherwise be unavoidable. The value of this feature of the work must be obvious to all.

In order to carry out the method thus proposed, the form of question and answer has been adopted, because the plan possesses peculiar advantages. It is calculated to concentrate the attention of the pupil upon the subject under immediate consideration; to dwell upon every point until perfectly understood; to define the precise limits of each proposition; and to afford means for enlarging the explanations without crowding the mind with ideas but imperfectly comprehended.

Short notes in smaller type have been introduced throughout the text, which serve to elucidate the figures and diagrams, and to convey more complete explanations of particular subjects. There is a series of notes at the end of the work, which will facilitate the advancement of those who may wish to enter more fully into this arduous yet fascinating study.

The maps, figures, and diagrams have been carefully drawn, and are executed in the best manner. Thus it will be seen that nothing has been spared to render this work useful and attractive to the pupil, as well as to the student of riper years; at once qualifying it to occupy a place in the school-room, the study, or the parlor.

An intimate knowledge of the heavenly bodies renders them as familiar as friends; so that he who can be induced to turn occasionally from the cares and disappointments of life to the study of the heavens will be amply recompensed by the rational entertainment which it affords.

Hilton, Crosswicks, N. J., 1856.

CONTENTS.

Introduction.

Q. What is Astronomy?

A. The science which treats of the *heavenly bodies*, describes their *appearances*, and the *laws* by which their motions are governed.

Q. Into how many parts may the science of Astronomy be divided?

A. Into *four* parts. *Physical*, *Descriptive*, *Sidereal*, and *Practical* Astronomy.

Q. What is Physical Astronomy?

A. Physical Astronomy treats of the *motions* of the heavenly bodies, and the *laws* which operate to produce them.

Q. What is Descriptive Astronomy?

A. Descriptive Astronomy is a *relation* or *description* of the appearances of the heavenly bodies belonging to the solar system.

Q. What is Sidereal Astronomy?

A. Sidereal Astronomy treats of the *Fixed Stars*, *Nebulæ*, &c.; or those bodies which do *not* belong to the solar system.

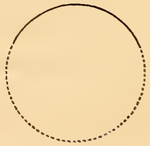
Q. What is Practical Astronomy?

A. Practical Astronomy treats of *astronomical instruments*, and their application.

The following definitions are inserted for the benefit of those who have never studied spherical Geometry; a knowledge of the circles of the sphere being of the utmost importance to the right understanding of the principles of Astronomy.

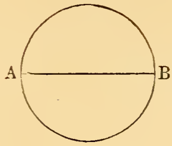
A *circle* is a figure contained by a uniform curved line, called its circumference, which is everywhere equidistant from a point within, called its centre.

Fig. 1.



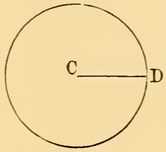
An *Arc* of a circle is any *part* of the circumference; consequently, in *fig.* 1, the dotted line, and also the black one, are arcs of the circle, because neither of them constitutes the *whole* circumference, but only a *part*.

Fig. 2.



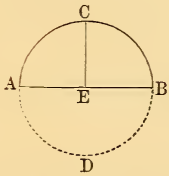
The *Diameter* of a circle is a line drawn through the centre and terminating at the circumference. A B is the diameter of the circle. *Fig.* 2.

Fig. 3.



The *Radius* of a circle is a line drawn from the centre to the circumference. C D is the radius of the circle in *fig.* 3.

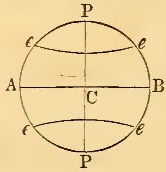
Fig. 4.



A *Semicircle* is half the circle, or a segment cut off by a diameter. A C B is a semicircle. A half circumference is sometimes called a semicircle. It contains 180°.

A *Quadrant* is half a semicircle, or one-fourth part of a whole circle. A quarter of a circumference is sometimes called a quadrant. B E C and C E A (*fig.* 4) are quadrants, all of which contain 90°.

Fig. 5.



A *Great circle* of a sphere is one whose plane passes through the centre of the sphere, as A B, (*fig.* 5.)

A *Lesser* or *Small circle of the sphere* is that whose plane does not pass through the centre of the sphere, but divides it into two unequal parts; as *e e*, in *fig.* 5.

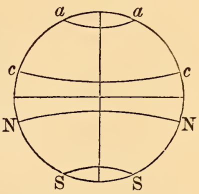
The *Axis* of the earth, or of a heavenly body, is that diameter about which it performs its diurnal revolution. In *fig.* 5, P C P represents the axis of the earth.

The *Poles* of a sphere are the extremities of its axis. P P (*fig.* 5) represent the poles of a sphere.

The *Equator* is an imaginary circle on the surface of the earth equidistant from the poles. In *fig.* 5, A B represents the equator.

The *Equator of the heavens*, or *Equinoctial*, is the terrestrial equator extended to the surface of the starry sphere.

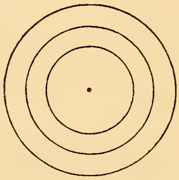
Fig. 6.



The *Tropics* are two lesser circles of the sphere, situated at the distance of 23° 28′ north and south from the equator. The tropic (*c c*, *fig.* 6) north of the equator is the tropic of Cancer; the tropic (N N) south of the equator is the tropic of Capricorn.

The *Polar circles* are two lesser circles situated at the distance of 23° 28′ from each pole. The north polar, or Arctic circle, is marked *a a*, (*fig.* 6,) and the south polar, or Antarctic circle, is marked S S.

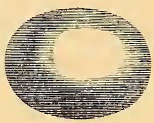
Fig. 7.



Concentric circles are circles of different diameters drawn round a common centre. *Fig.* 7.

A *Sphere* is a solid figure, every part of whose surface is equally distant from a point within, called its centre.

Fig. 8.



A *Spheroid* is a figure nearly spherical. It may be *prolate* or *oblate*. A lemon is in the form of a prolate spheroid, and an orange is in the form of an oblate spheroid. The earth is an oblate spheroid, though much less compressed than the figure.

Zenith, that point in the heavens directly overhead.

Nadir is that point in the heavens directly under the feet of the observer. The zenith and nadir are the *poles* of the *horizon.*

Vertical circles of the sphere are great circles passing through the zenith and nadir.

The *prime vertical* is a circle perpendicular to the meridian, which passes through the east and west points of the horizon.

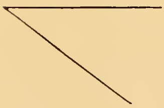
A *Hemisphere* is the half of a globe or sphere.

Meridians are imaginary circles drawn through the poles, and cutting the equator at right angles.

The *celestial sphere* is the concave surface of the heavens surrounding the earth in all directions.

Axis of the heavens is the axis of the earth extended to the concave surface of the celestial sphere.

Fig. 9.

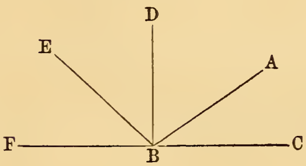


An *Angle* is the opening of two straight lines having different directions and meeting in a point.

Fig. 10.

A line is *perpendicular* to another when it inclines no more on one side than on the other, making the angles on both sides of it equal. *Fig.* 10.

Fig. 11.

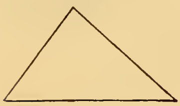


An *Acute angle* is less than a right angle; that is, less than 90°. A B C (*fig.* 11) is an acute angle.

A *Right angle* is that which is made by one line perpendicular to another; or, when the angles on each side of a perpendicular are equal to one another. In *fig.* 11, D B is perpendicular to F C, and the angles C B D and D B F are right angles, and equal to each other.

An *Obtuse* angle is greater than a right angle; that is, it contains more than 90°. C B E and A B F are obtuse angles.

Fig. 12.

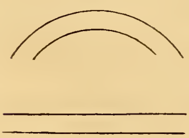


A *Triangle* is a figure bounded by three sides.

Fig. 13.

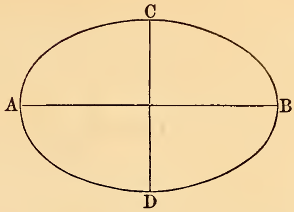
A *Parallelogram* is a figure which has its opposite sides equal and parallel.

Fig. 14.



Parallel lines are always at the same perpendicular distance from each other; they never meet, though indefinitely produced.

Fig. 15.



An *Ellipse* is an oblong plane figure, having two points, called its foci, around which the figure is described.

The *transverse* axis of an ellipse is the longer one A B, *fig.* 15.

The *conjugate* axis is the shorter one, marked C D.

Latitude on the earth is the distance of a place north or south of the equator, measured on the meridian.

Latitude of a heavenly body is its distance north or south of the ecliptic.

Longitude of a place on the earth is its distance east or west from any given meridian.

Longitude of a heavenly body is its distance from the first point of Aries, reckoned eastward on the ecliptic.

Declination of a heavenly body is its distance north or south of the equinoctial, measured on the meridian.

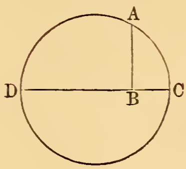
Right ascension.—The distance of any celestial body eastward from the point Aries, reckoned on the equinoctial.

The *Ecliptic* is that great circle in which the sun *appears* to move, but which is the *real path of the earth.* The poles of the equator are the poles of the earth; but the poles of the ecliptic do not correspond with those of the equator, but are 23° 28′ distant from it; therefore the ecliptic must be inclined 23° 28′ to the equator. If two rings be placed one within the other so that their circumferences shall not coincide, they will be inclined to each other, unless they be so placed as to cross each other at right angles, in which case they will be perpendicular to each other.

The *Equinoxes*, or *Equinoctial points*, are the points where the ecliptic and equator intersect each other. The *vernal* equinox is that point of the ecliptic in which the sun appears about the 21st of March; the *autumnal* equinox is his apparent place about the 22d of September. At both these points the sun is vertical to all inhabitants of the earth living at the equator.

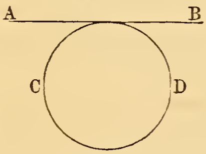
The *Solstices*, or *Solstitial points*, are those points of the ecliptic most distant from the equator. The solstices are situated 90° from the equinoxes. The *summer* solstice occurs about the 21st of June, and the *winter* solstice about the 22d of December.

Fig. 16.



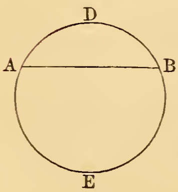
A *Sine* of any arc is the straight line drawn from one extremity of the arc perpendicular to the radius drawn to the other extremity. Thus A B is the sine of the arc A C, because it is drawn from A, which is at one extremity of the arc A C, and is perpendicular to the radius, which is half the diameter C D. Therefore, the radius meets the other extremity C of the arc A C. For the same reason A B is the sine of the arc A D, for it is drawn from A, which is one extremity of the arc A D, and is perpendicular to the radius, which, being one-half the diameter C D, meets the other extremity D of the arc A D. Therefore every sine is equal to two arcs, which together form a semicircle.

Fig. 17.



A *Tangent* is a straight line which *touches* but does not *cut* a curve. A B is a tangent to the circle C D. *Fig.* 17.

Fig. 18.



A *Chord* is a straight line connecting the two extremities of an arc. A B is a chord common to the two arcs A D B and A E B, which together constitute the whole circumference. *Fig.* 18.

PART I.

Physical Astronomy.

"Enrich me with the knowledge of Thy works!
Snatch me to Heaven; Thy rolling wonders there,
World beyond world in infinite extent,
Profusely scattered o'er the blue immense,
Show me. Their Motions, Periods, and their Laws,
Give me to scan. Through the disclosing deep
Light my blind way."

Q. Are the LAWS which govern the heavenly bodies similar to those observed on the earth?

A. They are; many of the *same laws* which are observed on the earth may be traced to the most *distant parts of the universe.*

CHAPTER I.

General Properties of Matter.

Q. What is MATTER?

A. Matter is any thing which is the *object of our senses.*

Q. Is every thing which we can SEE, TASTE, or FEEL, composed of matter?

A. Yes; also whatever is the object of the senses of *smelling* or *hearing.*

Q. How can the objects of the senses of SMELLING or HEARING be composed of matter?

A. The *odoriferous particles* which emanate from bodies are material, as also the air, the concussion of which produces sound.

Q. What are the GENERAL PROPERTIES of matter?

A. The principal qualities of matter are *magnitude, impenetrability, divisibility, compressibility, dilatability,* and *inertia.*

Q. What is MAGNITUDE?

A. It means *size* or *bulk.*

Q. Have ALL bodies magnitude?

A. All bodies *occupy space,* therefore they must have magnitude.

Q. What is meant by the IMPENETRABILITY of matter?

A. It cannot be penetrated without disturbing its *component parts.*

Q. What is the RESULT if a gimlet penetrate a board, or an oar penetrate the water?

A. In the first instance the component parts of the *board* are displaced by the *gimlet;* and in the second, the particles of *water* are displaced by the *oar.*

Q. What is understood by the DIVISIBILITY of matter?

A. Its capability of being *separated* or *divided.*

Q. Are ALL bodies divisible?

A. All *matter* is divisible, however minute it may be. (*See Note* 1.)

"Animalcules have been discovered so minute that thousands of them do not equal a grain of sand in bulk, yet, as these creatures have life and the power of motion, they may be supposed to be possessed of the functions of living beings. How exceedingly minute must be their heart, lungs, nerves, &c.! Yet the particles of light are infinitely more minute than these."

According to Ehrenberg, a cubic inch of water may contain more than 800,000,000,000 of animalcule; and a single drop placed under the microscope will be seen to hold 500,000,000; an amount, perhaps, nearly equal to the whole number of human beings on the globe!

"In thousand species of the insect kind,
Lost to the naked eye, so wondrous small,
Were millions joined, one grain of sand would cover all;
Yet each within its little bulk contains
A heart, which drives the torrent through its veins;
Muscles to move its limbs aright; a brain,
And nerves disposed for pleasure, and for pain;
Eyes to distinguish, sense, whereby to know
What's good, or bad, is, or is not, its foe."

Q. What is meant by the COMPRESSIBILITY of matter?

A. The diminishing its *bulk* or *size,* without destroying its component parts.

Q. Suppose a goblet to be inverted over a basin of water just so as to permit its rim to touch the surface of the water, what will the goblet CONTAIN?

A. The goblet will be filled with *air.*

Q. What would be the EFFECT if the goblet should be forced down into the water, without permitting the air to ESCAPE?

A. The water would rise some distance inside of the goblet, thereby proving the *compressibility* of the air.

Q. How does this PROVE the COMPRESSIBILITY of the air?

A. The air in the goblet was *compressed* by forcing the goblet down into the water without permitting the air to escape, causing it to occupy *less space* than before.

Q. What OTHER property of air does this experiment prove?

A. It proves the *impenetrability* of air; for it prevented the water from penetrating into its mass.

Q. Some bodies after being compressed return to their former dimensions; what is this property CALLED?

A. It is known by the name of *elàsticity.*

Q. Are all elastic bodies COMPRESSIBLE?

A. Yes; but all compressible bodies are *not elastic*, that is, they will not return to their original forms after being compressed.

India rubber is an elastic body.

Q. What is meant by the DILATABILITY of matter?

A. Its capability of *extension* without increasing its mass.

Take a bladder, the mouth of which is tied, so as to prevent the escape of the air from the inside, and place it under the receiver of an air-pump. Exhaust the air in the receiver, and the bladder will be observed to swell. This is owing to the external pressure of the surrounding air having been removed, which permits that in the bladder to dilate or expand.

Q. What is meant by INERTIA?

A. That quality of matter which implies *indifference* to either rest or motion—passiveness.

Q. What would be the EFFECT if a person be riding on horseback at a rapid pace, and the horse STOP SUDDENLY?

A. He would be thrown *over the horse's head.*

Q. WHY would he be thrown over the horse's head?

A. Because by reason of his *inertia* he would continue in the motion first imparted to him by the horse.

SECTION I.

Gravitation.

"That very law which moulds a tear,
And bids it trickle from its source,
That law preserves the earth a sphere,
And guides the planets in their course."

Q. What is meant by GRAVITATION?

A. That power which impels bodies *towards* each other.

Q. Why does a stone, when dropped from the hand, FALL to the earth?

A. Because the powerful attraction of the earth's *greater mass* impels the smaller body to move towards it.

Q. What would be the effect if the earth and the stone were of EQUAL mass?

A. They would fall towards each other, and *meet half way.*

Q. If a stone were abandoned to itself at a great distance from the earth's surface, would it fall TOWARDS the earth?

A. Yes; if the stone were several thousand miles distant it would as certainly *fall to the earth* as it does when dropped at the distance of a few feet.

Q. Would a stone, a thousand miles from the earth, WEIGH AS MUCH as it would at the earth's surface?

A. No; the power of gravitation *decreases* above the earth's surface, in proportion *as the square of the distance* from the earth's centre *increases.*

Q. Explain this.

A. A body which, at the surface of the earth weighs *one pound*, would at 4000 miles above the surface, that is, at double the distance of the surface from the centre, only weigh a *quarter* of a pound.

As the moon is about 240,000 miles from the earth, the attraction of the earth at that distance must be equal to the square of 240,000 divided by the square of 4000, the distance of the centre from the surface of the earth. By this method it is found that a body weighing one pound at the surface of the earth, would weigh the $\frac{1}{3600}$ of a pound at the distance of the moon.

Q. With what VELOCITY do bodies fall, which are situated near the surface of the earth?

A. Bodies near the earth's surface fall *sixteen* feet in the first second, *three times sixteen* in the next second, *five times sixteen* in the third second, and so on, continually increasing, according to the odd numbers 1, 3, 5, 7, 9, &c.

Q. What is the LAW of falling bodies?

A. The space through which a body falls increases in proportion to the square of the time it occupies in falling.

Q. Illustrate this law.

A. If a stone require *four* seconds to reach the ground from a high tower, the tower will be *two hundred and fifty-six* feet high. Because the stone would fall 16 feet in the first second, 3 times 16 in the next, 5 times 16 in the third, and 7 times 16 in the fourth, which, added together, make the sum of 256 feet.

Q. Is there a SHORTER method of obtaining the same result?

A. Yes; by squaring the number of seconds, and multiplying the result by 16; thus $4 \times 4 \times 16 = 256$.

Q. Does the attraction of gravitation act on ALL bodies?

A. It does; without any regard to their *figure* or *size*.

Q. Does it act MORE POWERFULLY on some bodies than on others?

A. It acts in proportion to the *quantity of matter* which they contain.

Q. Would a GREATER FORCE of gravity be exerted on a body weighing ten pounds, than on one weighing one pound?

A. A *ten times greater force* would be exerted on the body weighing ten pounds.

Q. Would two bodies of UNEQUAL weight fall to the earth in the same space of time?

A. Yes; they would fall to the earth with *equal* velocities. (*See Note* 2.)

Q. If, by the attraction of gravitation, all bodies are drawn to each other, why do they TEND to the EARTH?

A. The earth being so much *more vast* than any body on or near its surface, the effect of this attraction between smaller bodies is not perceptible. (*See Note* 3.)

DIVISION I.—CENTRE OF GRAVITY.

Q. What is the CENTRE of GRAVITY?

A. It is that *point* of a body upon which, if it be *freely suspended*, it will *rest.* The centre of gravity is no other than the centre of parallel and equal forces.

Q. Have ALL BODIES a centre of gravity?

A. Yes; there is a point in every body, of whatever form it may be, in which the *forces of gravity* may be considered as *united.*

Q. In what DIRECTION does a body, when not supported, endeavour to FALL?

A. In a line drawn from its *centre of gravity* towards the *centre of the earth.*

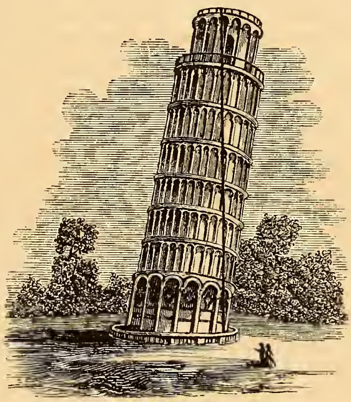
Q. What is that LINE CALLED along which every body when unsupported endeavours to fall?

A. It is called the *line of direction.*

Q. Why does a body sometimes STAND and at other times FALL?

A. If the line of direction fall *within the base*, it will stand; but if it fall *without the base*, it will fall.

Fig. 19.



There is a tower in Pisa, in Italy, which leans so much as to appear as if it would fall; but its line of direction falls within the base, so that it will be likely to stand in its present position until its materials fall into decay.

Q. In what part of a GLOBE is the centre of gravity placed?

A. In the *centre.*

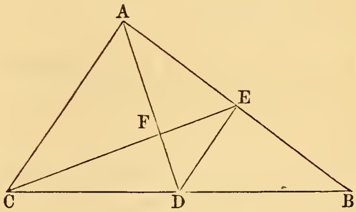
Q. The earth is an oblate spheroid; in what part of the EARTH is its centre of gravity?

A. In its *centre.*

Q. In IRREGULARLY FORMED bodies where is the centre of gravity situated?

A. It is always situated near the *largest portion* of the mass.

Fig. 20.



In order to find the centre of gravity of the triangle A B C, (*fig.* 20,) draw a line from the point A to D, situated at the middle of the base. This line A D equally divides all those lines which may be drawn parallel to B C: the centre of gravity will be found on the line A D. From the point C to the middle of the opposite side A B, draw the line C E: the centre of gravity will be found on this line also; and as it lies somewhere on the line A D, it must be at their intersection at F. Now draw the line E D; and as A C : D E :: A F : F D; but A C is double D E; then A F must also be double F D, and consequently the centre of gravity of a triangle is situated on a line drawn from the highest point, and at two-thirds of its length from its base.

Q. In what part of a CONE is the centre of gravity situated?

A. At a point about *one-fourth* of its height from its base.

Q. Why will a cone stand MORE FIRMLY than a cylinder?

A. Because in the cone the centre of gravity is situated *near the base*, while that of the cylinder is *midway* between its extremities.

Q. If persons were to be overtaken by a squall of wind while in a small boat, in what POSITION should they place themselves?

A. They would incur less risk by *sitting in the bottom of the boat.*

Q. WHY would that be the safest position?

A. Because by sitting in the bottom of the boat they *lower* their *centre of gravity.*

Q. Why does a man stand with his FEET APART when driving a cart?

A. Because by increasing his base he lowers his centre of gravity.

The broader the base, the nearer is the line of direction to the middle of it.

Q. Why are all SPHERICAL bodies more easily moved than bodies of any other form?

A. Because the base is a mere point, and consequently the *line of direction* is easily moved *beyond* the base.

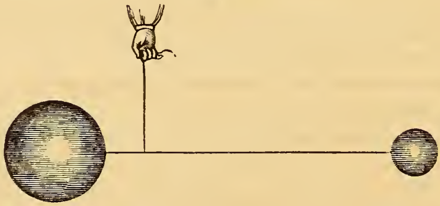
Q. Suppose two balls of EQUAL SIZE be united by a stiff wire, where would the centre of gravity be situated?

A. At a point in the wire *equidistant* from each of them.

Q. Suppose one of the balls to be THREE TIMES heavier than the other, where would the centre of gravity be situated?

A. It would be *three times* nearer to the large ball than to the small one. (*See Note* 4.)

Fig. 21.



The sun is so much larger than the earth and all the planets put together, that the centre of gravity of the solar system is situated *within* the globe of the sun.

DIVISION II.—SPECIFIC GRAVITY AND DENSITY.

Q. What is understood by SPECIFIC GRAVITY?

A. It denotes the *weight* of a body, as compared with the weight of an *equal bulk* of some other body taken as a standard.

Q. What OTHER BODY is commonly used as a standard of unity!

A. The standard commonly used is *distilled water*, at the temperature of 60° Fahrenheit; but any other substance would answer as well as water.

Q. What is meant by DENSITY?

A. By the density of a body is meant its *mass*, or *quantity of matter*, compared with that of an equal volume of water, or some other body taken as a standard.

The density of a body is the relation of its weight to its volume.

Q. Would a cubic inch of water and a cubic inch of steel hold each other in EQUILIBRIUM?

A. No; although their masses measure the same, the steel is nearly *eight times more dense* than the water.

Q. How MANY cubic inches of water would be required to balance the cubic inch of steel?

A. It would require nearly *eight cubic inches of water* to balance one of steel.

The specific gravity of steel is nearly eight times that of water. Thus, we say ice is less dense than water, and water less dense than gold, silver, steel, &c.

SECTION II.

General Laws of Motion.

Q. What is MOTION?

A. Motion means *change of position;* the act of moving.

Q. When is a body said to be IN MOTION?

A. When it successively occupies *different positions* at *different times.*

Q. How is motion CLASSIFIED, or divided?

A. It is classified into three kinds, viz. *Absolute* motion, *Relative* motion, and *Apparent* motion.

Q. What is ABSOLUTE motion?

A. Absolute motion is a change of position with regard to a *stationary point.*

Q. What is RELATIVE motion?

A. Relative motion is a change of position in a body, with *respect to another body* also in motion.

Q. What is APPARENT motion?

A. Apparent motion is due to a change of place in the observer, which produces a change in the lines of vision between certain fixed objects and himself.

Q. When is a body said to be in a state of REST?

A. When a body is *immovable* or *motionless*, it is said to be in a state of *rest*.

Q. Can a body be said to be in a state of ABSOLUTE REST?

A. No; as it is supposed there is nothing in nature without motion, there can be *no absolute*, only *relative* rest.

Q. Has a body in a state of rest the power to CHANGE ITS POSITION?

A. A body in a state of rest *cannot impart motion to itself.*

Q. Has a body in motion the power to change its RATE OF MOTION?

A. A body in motion cannot of *itself* change or annihilate its condition of motion.

Q. How can a change of motion be PRODUCED?

A. It requires some external resistance to *put an end* to motion, and also some force must be impressed on a body in order to *put it in motion.*

Q. What RESISTANCE does a ball receive when fired from a cannon?

A. Its motion is checked

1. By the attraction of gravitation, and
2. By the resistance of the air.

Q. If a marble be rolled over smooth ice, or a gravel walk, what finally STOPS its motion?

A. It is checked by *friction.*

Q. What is the IMPETUS or quantity of motion of a moving body called?

A. It is called *momentum*, or *force of motion.*

Q. On what does the momentum of a moving body DEPEND?

A. It depends

1. On its weight, and
2. On the velocity of its motion.

Q. How does a moving body acquire its MOMENTUM?

A. It acquires it from some *other agent* already in motion.

Q. Can one body confer momentum on another without losing the SAME AMOUNT itself?

A. No; momentum is always a *communicated property.* Every body loses the same amount of momentum which it imparts; and every body that acquires momentum takes what another has lost. (*See Note* 5.)

SECTION III.

Compound Motion.

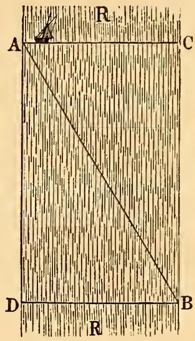
Q. What is COMPOUND MOTION?

A. Compound motion is that which is produced by the combination of *two or more forces*, acting in different, but not opposite directions.

Q. How does a body MOVE when impelled in two different directions?

A. It moves in a direction *intermediate* to those two forces.

Fig. 22.



Suppose R R to be a river, and that a boat starts from A to cross the stream, and endeavours to arrive at the point C. If, at the same time, the current is running towards D, the boat goes neither to C nor D, but moves on to B in a direction intermediate to the current and the force of the rower. Each force modifies the influence of the other, and brings its power to bear in a new direction, without destroying it, unless the two forces act in directly opposite lines, and with equal influence; in which case the one entirely neutralizes the other.

Q. What KIND of motion is that called which is the result of two or more combined forces?

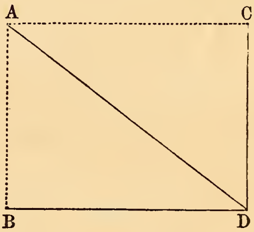
A. It is called *compound motion.*

Q. What is the LINE called which indicates the direction of this compound motion?

A. It is termed the *mean* or *resultant.*

In the foregoing figure the line A B is the resultant of the two forces A D and A C. It will be seen that the lines A D and A C, which represent the forces, form two sides of a parallelogram, the diagonal of which, A B, is the mean; hence it is called the *parallelogram of forces.*

Fig. 23.

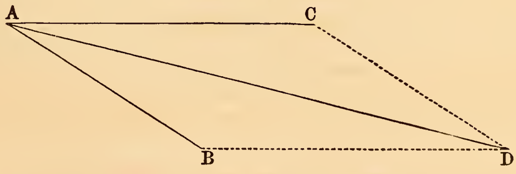


The resultant of two forces is found thus. In *fig.* 23 we have the two forces A C and A B acting in different directions; the one of itself would have driven a body from A to C, and the other from A to B. But it obeys both forces by following the line A D, which is the *mean* or *resultant.* If the lines C D and B D be drawn parallel to A C, their point of intersection at D forms the extremity of the resultant A D.

Q. Do the different forces act with the same power at ANY ANGLE?

A. No; the combined forces act with more power at an *acute* than at an *obtuse angle.* As the angle decreases, the effect of the united forces increases.

Fig. 24.



In *fig.* 24 the point A, from which the combined forces A C and A B proceed, is an acute angle, and hence the diagonal which represents the resultant will be increased.

Now, should the angle C A B be reduced till it vanishes, or, which is the same thing, when the sides A C and A B coincide, the combined forces will have their greatest effect. But should the forces be equal, and act in opposite directions *in a straight line,* they will destroy each other.

DIVISION I.—CURVILINEAR MOTION.

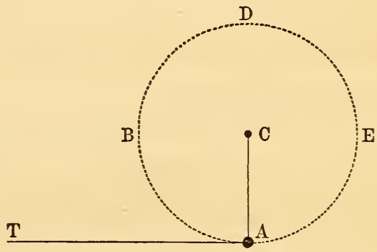
Q. What is CURVILINEAR motion?

A. Curvilinear motion is motion in a *curved line.*

Q. Suppose a blow be given to a ball suspended by a thread, in what DIRECTION would it move?

A. Its motion would be in a *curved line,* because the thread would prevent it from moving in a straight one.

Fig. 25.



If a blow be given to the ball at A, it would move in the straight line A T, if it were not attached to the thread which is fastened at the point C; consequently it is held by the thread, and moves in the curved line A B D E.

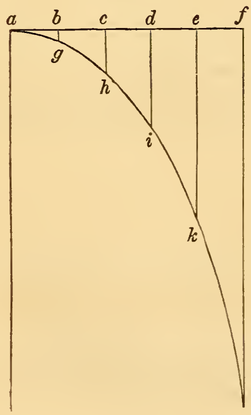
Q. What is a PROJECTILE?

A. A body which is *projected* or *thrown.*

Q. Does a projectile always describe a CURVED LINE?

A. Yes; if it be thrown in any other than a *vertical* direction, it will describe a curve.

Fig. 26.



The curve *a g h i k* represents the path of a projectile. By reason of the first impulse, it would require one second to travel over the space *a b,* and if there was no such force existing as gravity, it would traverse the space *b c* in the next second, and so on. But in the first second it fell to *g,* in the next to *h,* and in the third, instead of being at *d,* it has moved to *i,* and in the fourth second it has arrived at *k.*

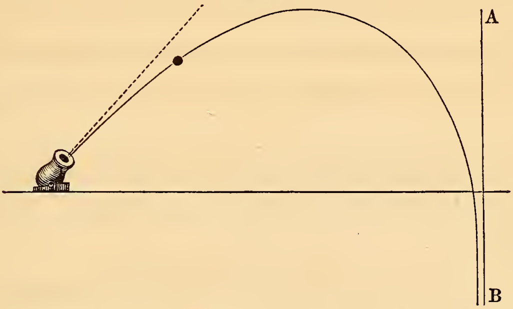
Q. What is the COURSE described by a projectile when thrown in any other than a vertical direction?

A. The curved line described by a projectile in free space is a *parabola.*

Q. Why does not a projectile describe a parabola when near the surface of the EARTH?

A. Because the *air* offers sufficient resistance to change its curve.

Fig. 27.



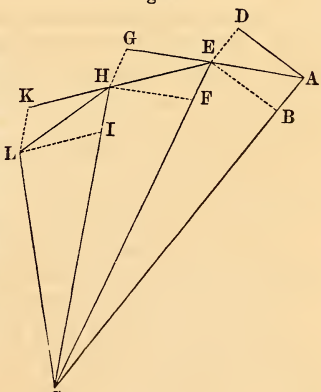
Taking into consideration the resistance of the air, it will be seen that the curve described is not a perfect parabola. The line A B is its *asymptote.*

Asymptote.—A right line, which continually approaches nearer and nearer to a curve without ever meeting it.

Q. Could a body be made to move in a curved line by the action of a SINGLE FORCE?

A. No; every body which moves in a curved line must be acted on by at least *two forces.*

Fig. 28.



Let C (*fig.* 28) be the point towards which a body at A is continually attracted; but let us suppose that the body receives at the same time an impulse in the direction A D. In the first second the central force tends to drive the body from A to B, and the lateral force impels it from A to D; it follows the diagonal A E of the parallelogram. As soon as it arrives at E, it is still inclined to proceed in the straight line to G, but is attracted by the central force C towards F; consequently it pursues the path E H, the diagonal of the parallelogram E F H G. When at H, owing to the same reason, it pursues the path H L. Thus the body describes the curve A E H L. But as the central force acts equally and without intermission, the path the body would pursue would be a perfect curve. The diagram, however, serves to elucidate the principle.

Curvilinear motion is no other than a series of uninterrupted movements in straight lines, forming very obtuse angles.

DIVISION II.—CENTRIFUGAL AND CENTRIPETAL FORCES.

Q. How is CURVILINEAR MOTION, or motion round a CENTRE, produced?

A. It is produced by two powers, one of which is called the *centrifugal*, the other the *centripetal force.*

Q. If a stone be whirled in a sling, what TWO FORCES act upon the stone?

A. The force or power of *the string*, which retains the stone, and the force or power of *the hand*, which keeps it in a circular motion.

Q. If the string were cut while being whirled round, would the stone fly off in a CURVED LINE?

A. No; the stone would fly off in a line at *right angles* with the string.

Q. What causes the stone to fly off at RIGHT ANGLES with the string?

A. The *projectile force* given to it by the hand impels it in a straight line; but the force of the string changes its course into that of a curve.

Projectile Force.—That power which impels a body onward.

Q. What is this projectile force called when applied to the PLANETS?

A. It is called *centrifugal force.*

Centrifugal.—Flying or receding from the centre.

Q. What would be the EFFECT if some dry sand were placed on the edge of a wheel when the wheel is revolving rapidly?

A. The particles of sand would fly off the rim at a *tangent;* that is, at right angles to the spokes of the wheel.

Q. What FORCE causes the particles of sand to fly off the edge of the wheel?

A. It is the *projectile* or *centrifugal force.*

Q. Do the particles of sand fly off the wheel in a CURVED, or a STRAIGHT line?

A. They fly off in *straight lines*, at right angles to the spokes; but the force of gravity brings them to the ground in a *curve.*

Q. What is that FORCE OR POWER which is constantly urging a revolving body towards the centre of motion?

A. It is called *centripetal force.*

Centripetal.—Tending to the centre. Centripetal force and the attraction of gravitation are terms of the same import.

Q. How may centrifugal force be INCREASED?

A. By increasing the *velocity of the revolution* of a body. Centrifugal forces are proportioned to the *squares of their velocities.*

Q. Give an EXAMPLE to illustrate this rule.

A. If the velocity of a revolution be increased *three times*, the centrifugal force will be *nine times* greater, because nine is the square of three; if it were increased *twenty times*, the centrifugal force, for the same reason, would be *four hundred times* greater. *(See Note* 6.)

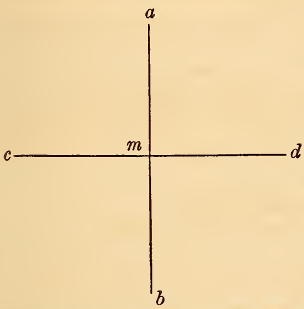
CHAPTER II.

Angular Measurement.

Q. WHAT is an ANGLE?

A. It is the *opening* between two straight lines, drawn from the same point; or, in other words, the amount of *divergence* separating two straight lines drawn from the same point.

Fig. 29.



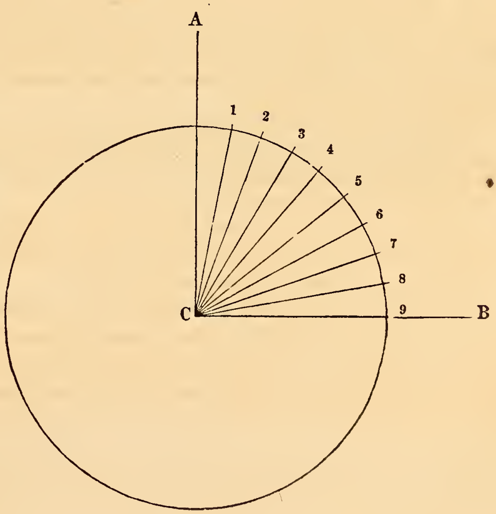
In the accompanying figure, the opening between the two straight lines *a m* and *c m* constitutes an angle. The openings between each of these lines form four different angles, the point *m* being the *vortex,* or *angular point.*

Q. How can the AMOUNT OF DIVERGENCE between two straight lines, drawn from the same point, be estimated?

A. In order to determine the size of an angle, the circle is employed. For this purpose observe what *proportional part* of the circumference of the circle is contained between the lines.

Fig. 30.

Draw a circle round C, (*fig.* 30,) and it will be seen that one-fourth of the circular space is included between the lines C A and C B. The amount of the angle or space included between the lines C A and C B, is measured off on the circumference of the circle.



Q. What kind of an angle is that which includes the FOURTH PART of a circle between its sides?

A. It is called a *right angle.*

A C B (*fig.* 30) comprises the fourth part of the circle, therefore it is a right angle. Observe a certain spoke of a wheel when it points directly upwards, and turn the wheel until that spoke is horizontal, that is, parallel with the horizon, and you will have caused the spoke to have changed its position by the fourth part of a circle, or a right angle.

Q. How many RIGHT ANGLES are there contained within the circumference of a circle?

A. Every circle comprises *four right angles* within itself. Therefore, every right angle must equal the fourth part of a circle.

Q. Into how MANY PARTS is a circle usually divided, for the purpose of measurement by angles?

A. The circle is divided into 360 equal parts called degrees, and each degree into 60 equal parts called minutes, and each minute into 60 equal parts called seconds.

60 seconds	marked	$''$	= one minute.
60 minutes	"	$'$	= one degree.
360 degrees	"	$^\circ$	= one great circle.

Seventy-five degrees, forty minutes, and fifty-three seconds, is written thus: $75^\circ\ 40'\ 53''$.

Q. How many DEGREES are contained in a right angle?

A. As a right angle is the *fourth part* of a circle, and as a circle contains 360 degrees, it follows that a right angle must contain the fourth part of 360 degrees, which is 90 degrees.

Q. For WHAT PURPOSE is this subdivision of circles into angular segments?

A. It is for the purpose of enabling observers to determine the *apparent position* of objects with great accuracy.

Q. What is meant by the APPARENT POSITION of objects?

A. Their position, so far as it can be determined by *sight* alone.

The apparent position must not be confounded with the *absolute* or *real* position of objects. Objects may be very little asunder, *apparently,* which are in *reality* very far apart. Thus, two trees in a line with the eye may appear to touch, although they may be separated by several yards.

Q. Why is angular measurement of so much IMPORTANCE in Astronomy?

A. Because by angular measurement the astronomer discovers the distances and dimensions of the heavenly bodies. (*See Note* 7.)

PART II.

Descriptive Astronomy.

CHAPTER I.

The Solar System.

"The Sun revolving on his axis turns,
And with created fire intensely burns;
Impell'd the forcive air, our earth supreme
Rolls with the planets round the solar gleam.
First, Mercury completes his transient year,
Glowing refulgent with reflected glare;
Bright Venus occupies a wider way,
The early harbinger of night and day.
More distant still, our Globe terraqueous turns,
Nor chills intense, nor fiercely heated burns;
Around her rolls the lunar orb of light,
Trailing her silver glories through the night.
Beyond our globe, the sanguine Mars displays
A strong reflection of primeval rays:
The group of Asteroids in order move
Between the planets Mars and mighty Jove.
Next, belted Jupiter far distant gleams,
Scarcely enlightened with the solar beams.
With four unfixed receptacles of light,
He towers majestic through the spacious height;
But farther yet the tardy Saturn lags,
And eight attendant luminaries drags;
Investing with a double ring his pace,
He travels through immensity of space.
Next, see Uranus wheeling wide his round
Of fourscore years; not unassisted found
By human eye; the telescope displays
Him, with six moons, to philosophic gaze.
Still more remote, pale Neptune wends his way;
Le Verrier's skill divined his distant ray.
His lengthened year, by his slow-moving pace,
A hundred sixty-four of ours may trace."

Q. Why is the solar system so called?

A. It is called solar from *Sol*, the *Sun*.

Q. Of what does the solar system consist?

A. It consists of the *Sun*, the *planets*, with their *satellites* or *moons*, and the *comets*.

Q. Where is the Sun SITUATED?

A. In the centre of the system, the planets and comets revolving around him.

Q. What are the PLANETS?

A. Those bodies with *well-defined discs*, which revolve round the Sun, and receive their light and heat from him.

The planets and satellites always show well-defined discs when viewed through the telescope, although to the naked eye some are entirely invisible.

Q. What are SATELLITES?

A. The moons of a planet. Our Moon is a satellite of the Earth.

Q. What are COMETS?

A. They are bodies which revolve around the Sun, but which, unlike the planets, have generally *no well-defined discs.*

CHAPTER II.

The Sun.

"Of all the products of the fertile earth, there is not one which is not called into activity, and brought to maturity, by the action of the Sun; neither is there a streak upon a leaf, or a tint upon a flower, but what is limned by the orb of day. Thus, the heavens become, in the strictest sense of the word, the keys to the knowledge of universal nature."

"Fairest of beings! first created light;
Prime cause of beauty! for from thee alone
The sparkling gem, the vegetable race,
The nobler worlds that live and breath their charms,
The lovely hues peculiar to each tribe,
From thy unfailing source of splendour draw!
In thy pure shine with transport I survey
This firmament, and these her rolling worlds,
Their magnitudes and motions."

Q. What is the SUN?

A. An enormous globe of *dense matter*, from which light and heat are constantly emanating.

Q. How can it be proved that the Sun is composed of DENSE MATTER?

A. It is known to exert an *attractive* influence on all the bodies belonging to the solar system, which is a proof of its being composed of dense matter.

Q. How is it known that LIGHT and HEAT emanate from the Sun?

A. Both light and heat are perceived when the observer is on that side of the Earth which is *turned towards the Sun;* for when we stand in the sunshine, we not only see the light, but feel the heat.

Q. Is the entire body of the Sun LUMINOUS?

A. No; its light is supposed to emanate from its *outer surface.*

By means of a telescope, spots may sometimes be seen, which are now presumed to be the dark body of the Sun seen through apertures in its outer luminous envelope.

Q. Of what is the luminous surface of the Sun supposed to CONSIST?

A. The outer envelope of the Sun is supposed to consist of a *luminous gas*, which the telescope shows to be in motion, and occasionally parted or broken, so as to reveal the dark body of the Sun through the openings. (*See Note* 8.)

Q. What is the DISTANCE of the Sun from the Earth?

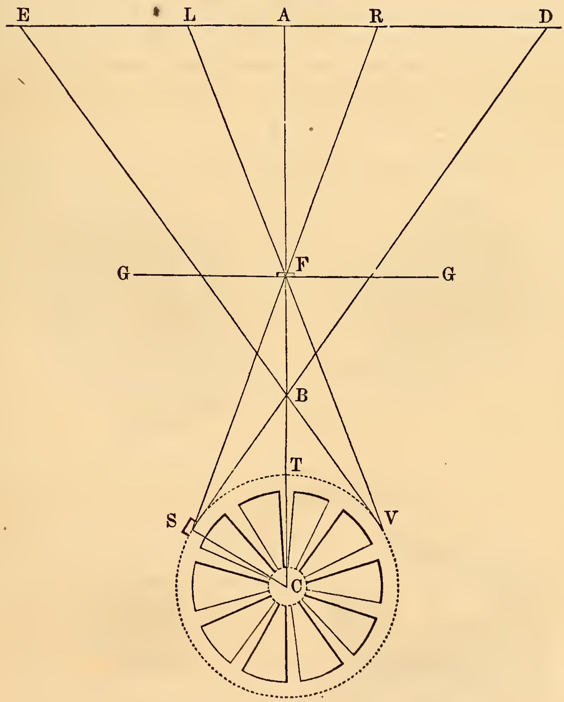
A. About *ninety-five millions of miles.*

Light, which moves at the rate of about 200,000 miles in a second, requires nearly eight minutes and a quarter to travel from the Sun to the Earth; and a railroad car, moving at the rate of thirty miles an hour, would require *three hundred and sixty years* to travel from the Earth to the Sun.

Q. If the distance of the Sun be so immense, how can it be ASCERTAINED?

A. By noting the *different positions* it seems to occupy in the heavens, when viewed by two observers on the Earth's surface, stationed widely asunder.

Fig. 31.



In order to understand how it is that the distance of a remote body may be ascertained by viewing it from different positions, imagine S (*fig.* 31) to be a spider standing upon the rim of a wheel, and looking up at a fly placed at F, upon the pane of glass

G G, overhead. If the spider were as good a practical mathematician as he is sometimes believed to be, he would be able to ascertain the distance of the fly without leaving his wheel. He would first note the direction in which he saw the fly from S; he would then walk along the rim of the wheel to T, its top, and note the direction of the fly again. Next, he would continue his walk to V, and observe the direction for the third time. Now, when the spider was at T, he would have seen the fly directly overhead, projected against the sky as if at A, (the same precise spot, be it observed, against which he would have seen him projected if he had been looking at him from C, the centre of the wheel;) but when at S, he would have seen him depicted against the sky at R, a spot considerably to the right of A; and when at V, he would have seen him as if at L, considerably to the left of A. The distance between L and R, the extreme left and right apparent positions of the fly, would depend upon the length T F, the distance of the fly from the wheel; for, it will be observed, that if the fly had been at B instead of at F, the lines representing the direction in which he was seen from S and V would have crossed each other as the lines S D and V E do. The greater the change in the apparent position of the fly, caused by the spider's removal through the definite distance between S and V, the nearer must be the true place of the fly. The measure of the change of apparent position, as from L to R, or from E to D, therefore expresses the length of F T, or B T, the distance of the fly from the wheel.

Man, on the Earth, is a practical mathematician in similar circumstances to the spider on the wheel. He moves on the circumference of the Earth, as the spider does on the rim of the wheel, and notes the position which the Sun seems to occupy, first as seen from one side of the Earth, and then as seen from the other side; the distance between his positions being known, the true distance of the Sun from the Earth may be found by an easy mathematical process. When a fourth part of the entire circumference of the Earth intervenes between the two positions from which the observation is made, the difference of the Sun's apparent place in the heavens amounts to what is called eight seconds of space; that is to the 240th part of the breadth of the Sun's disc.

Q. How does the Sun APPEAR when viewed through a TELESCOPE?

A. Dark spots are often seen on the Sun's disc by the aid of the telescope.

Fig. 32.

Some of the solar spots are of immense size, and as changes are seen to take place in them in the space of a few hours, the fluctuations must be very rapid.

The spot No. 1, taken from drawings made by Sir John Herschel at the Cape of Good Hope, contained an area of at least 400,000,000 square miles; and the black centre of that represented in No. 4, was at least 10,000 miles in diameter, which was sufficiently large to allow the globe of our Earth to drop throught it, and leave a space of a thousand miles around it clear of contact.

The spots are considered by Sir J. Herschel to have an intimate connection with the rotation of the Sun upon his axis, which may possibly cause currents analagous to our trade-winds; for the spots are seen to occupy zones corresponding to our trade-wind regions.

Q. What APPEARANCE have these spots through a telescope?

A. They are frequently *large, and perfectly black*, surrounded by a margin or border less dark than the centre of the spot.

Q. What is this margin or border CALLED?

A. It is called a *penumbra.*

Q. Are the spots PERMANENT?

A. No; they appear to *enlarge* and *contract*, and often disappear in a few hours, or even less time. Sometimes they break out anew in parts of the surface where there were none.

Q. Are these spots very EXTENSIVE?

A. Some of them are immense, having been known to have a diameter of upwards of *forty-five thousand miles*, and even of a much greater extent.

Q. Is that part of the Sun's disc, unoccupied by spots, UNIFORMLY BRIGHT?

A. No; its *ground* is finely mottled with small *dots* or *pores*, which, when attentively watched through a telescope, are found to be in a constant state of change.

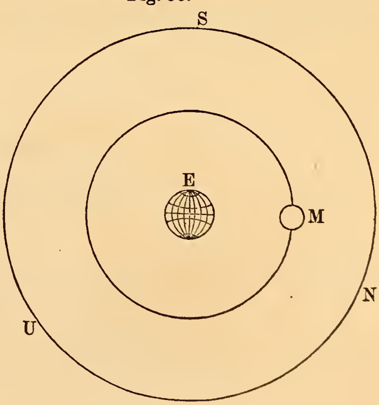
Q. Are there any other PECULIARITIES observable on the surface of the Sun?

A. Yes; in the vicinity of large spots strongly-marked *curved* or *branching streaks* may be observed, more luminous than the rest.

Q. What are these luminous streaks CALLED?

A. They are called *faculæ*, and the black spots are called *maculæ.*

Fig. 33.



If the centre of the Earth were placed at the centre of the Sun, the Sun would fill up the whole orbit of the Moon, and extend two hundred thousand miles beyond it. Let E (*fig.* 33) represent the Earth, and M the Moon in her orbit, which is two hundred and forty thousand miles from the Earth. The Sun would fill up the orbit of the Moon, and extend two hundred thousand miles beyond it, to the circle S U N.

Q. What is the SUPPOSED THICKNESS of the luminous coating or atmosphere of the Sun?

A. Sir William Herschel supposed it to be from two to three thousand miles in thickness.

Q. What is the MAGNITUDE of the Sun?

A. The Sun is *eight hundred and eighty-eight thousand miles* in diameter, or about one hundred and eleven times the diameter of our globe.

Q. What is the FORM of the Sun?

A. It is in the form of a *spheroid*, being slightly flattened at the poles.

Q. Is the Sun at REST?

A. No; it *revolves upon its axis*, as a ball would do if hung by a thread and made to spin round.

Q. How is it KNOWN that the Sun revolves on its axis?

A. Because the dark spots seen upon his disc *appear to move* from one edge across to the other edge, and then disappear.

Q. Why is the Sun believed to be SPHERICAL?

A. Because the spots may be seen crossing its disc exactly as they would if they were marks upon the surface of a *revolving ball.*

Q. How long does it take the Sun to complete ONE REVOLUTION on its axis?

A. It revolves on its axis once in about *twenty-five days.*

Q. If we know the diameter of two globes, can we estimate their BULKS?

A. We can; the bulks or relative contents of two globes of unequal magnitudes are to each other as the *cubes of their diameters:* that is, their diameters three times multiplied by themselves.

Q. What PROPORTION does the bulk of the Sun bear to that of the Earth?

A. The diameter of the Sun is rather more than one hundred and eleven times the diameter of the Earth. Therefore the volume or bulk of the Sun must be nearly *one million four hundred thousand* times that of the Earth.

If all the bodies composing the solar system were formed into one globe, it would be only about the five hundredth part of the size of the Sun.

CHAPTER III.

Interior Planets.

"With what an awful world-revolving power
Were first the unwieldy planets launched along
The illimitable void! There to remain
Amidst the flux of many thousand years,
That oft has swept the toiling race of men,
And all their laboured monuments, away

Firm, unremitting, matchless in their course;
To the kind-tempered change of night and day,
And of the seasons, ever stealing round,
Minutely faithful. Such the all-perfect Hand,
That poised, impels, and rules the steady whole.

THOMSON.

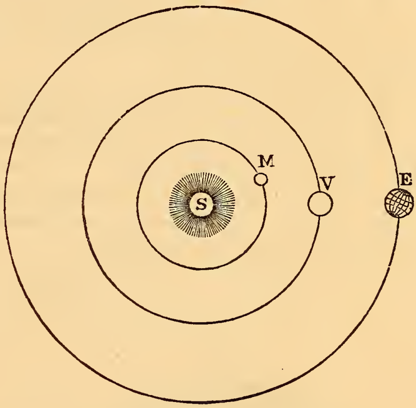
Q. What is meant by INTERIOR planets?

A. Interior, or as they are sometimes called, inferior, planets, are those whose orbits are *within* that of the Earth.

Q. How MANY interior planets are there, and what are their NAMES?

A. There are *two* interior planets, *Mercury* and *Venus*.

Fig. 34.



In *fig.* 34, let S be the place of the sun; M, the orbit of Mercury; and V, that of Venus. It will be seen they are both within or *interior* to the orbit of the Earth, E.

SECTION I.

Mercury. ☿

Q. What is the name of the planet NEAREST to the Sun?

A. The nearest known planet to the Sun is *Mercury*.

"Mercury, the first,
Near ordering on the day, with speedy wheel
Flies swiftest on, inflaming where he comes,
With sevenfold splendour, all the azure road."

Q. What is the DISTANCE of Mercury from the Sun?

A. Mercury is *thirty-seven millions* of miles from the Sun.

Q. Is Mercury as LARGE as our Earth?

A. No; his diameter does not exceed *three thousand miles;* whereas the Earth is about eight thousand miles in diameter.

Q. Does Mercury move ROUND THE SUN?

A. Yes; he performs one revolution round the Sun in about *eighty-eight* of our days.

Q. How long, then, is Mercury's YEAR?

A. About *eighty-eight days*, or rather less than *three of our months.*

Q. What produces the change of DAY and NIGHT?

A. The *revolution* of a planet on its axis.

Q. Does MERCURY revolve on his axis?

A. It is believed he revolves on his axis once in about *twenty-four hours.*

The time of his revolution on his axis cannot be ascertained with exactness, on account of his proximity to the Sun.

Q. How long, then, is Mercury's day?

A. *Twenty-four hours*—the same length as our day.

Q. At what RATE does Mercury move in his orbit round the Sun?

A. He travels at the immense rate of *one hundred and nine thousand* miles per hour.

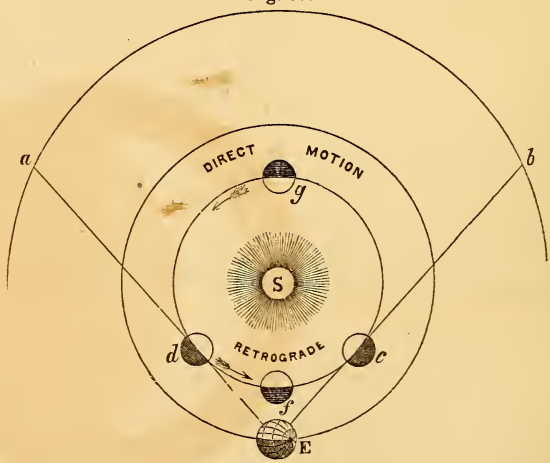
Q. Is Mercury ever seen on the MERIDIAN at midnight; that is, in that part of the heavens DIRECTLY OPPOSITE to the Sun's place?

A. No; Mercury is never seen more than about *thirty degrees east or west* from the Sun.

Q. Why is Mercury never seen FARTHER from the Sun than thirty degrees?

A. Because he revolves round the Sun in an orbit *included within* the orbit of the Earth.

Fig. 35.



In *fig.* 35, E represents the Earth in her orbit, and *c, g, d, f,* one of the interior planets in its orbit within that of the Earth. Let *a b* represent the concave sphere of the fixed stars. When the planet is at *c*, it is for some time receding in a line from the Earth, and, therefore, to us appears stationary. From *c* to *g*, and from *g* to near *d*, the motion appears direct, or from west to east; when near *d*, it is then approaching the Earth in an almost straight line, which makes it appear stationary; and from *d* to *f*, and from *f* to *c*, its motion appears retrograde, or contrary to the order of the signs.

Hence, it may be seen, that an inferior planet never appears at a greater angular distance from the Sun, among the stars, than from *a* on one side to *b* on the other side. These two points are called its greatest eastern and western elongations.

Q. As Mercury is so much nearer to the Sun than the Earth, does he receive more HEAT?

A. The heat at the planet Mercury is supposed to be *seven times* greater than on the Earth.

Mrs. Somerville says, "On Mercury, the mean heat arising from the intensity of the Sun's rays, must be above that of boiling quicksilver; and water would boil even at his poles." But he may be provided with an atmosphere so constituted as to absorb or reflect a great portion of this superabundant heat, so that his inhabitants (if he has any) may enjoy a climate as temperate as any on our globe.

"First, Mercury, amidst full tides of light,
Rolls next the Sun, through his small circle bright;
Our Earth would BLAZE beneath so fierce a ray,
And all its marble mountains melt away."

SECTION II.

Venus. ♀

Q. What is the NAME of that planet situated nearest to the Earth?

A. It is called *Venus.*

"Fairest of stars, last in the train of night;
If better thou belong not to the dawn.
Sure pledge of day, that crown'st the smiling morn
With thy bright circlet, praise Him in thy sphere,
While day arises, that sweet hour of prime."—MILTON.

Fig. 36.

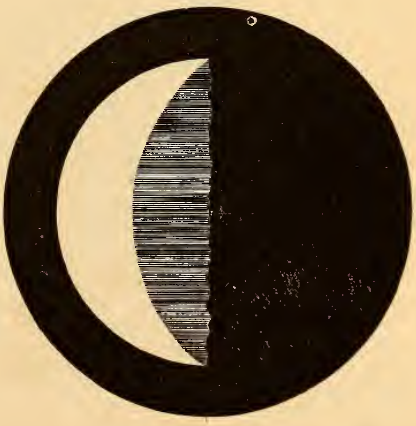


Fig. 36 is a telescopic view of Venus when only half her illuminated disc is turned towards the Sun.

Q. Why does Venus SHINE SO BRIGHTLY?

A. Because being *nearer to the Sun* than the Earth, she receives more of his light; and, being comparatively *near to the*

Earth, reflects on us a large portion of the solar light which she receives.

Q. Is the body of Venus OPAQUE, or LUMINOUS?

A. Venus, as well as the Earth, and all the other planets, is *opaque*.

Q. If the body of Venus be opaque, how does it SHINE so brightly?

A. Like our moon, she shines by *borrowed sunlight*.

Q. How is it KNOWN that Venus BORROWS her light from the Sun?

A. That half of the planet which is towards the Sun is *illuminated*, whilst the other half is *dark*, and, consequently, sheds no light.

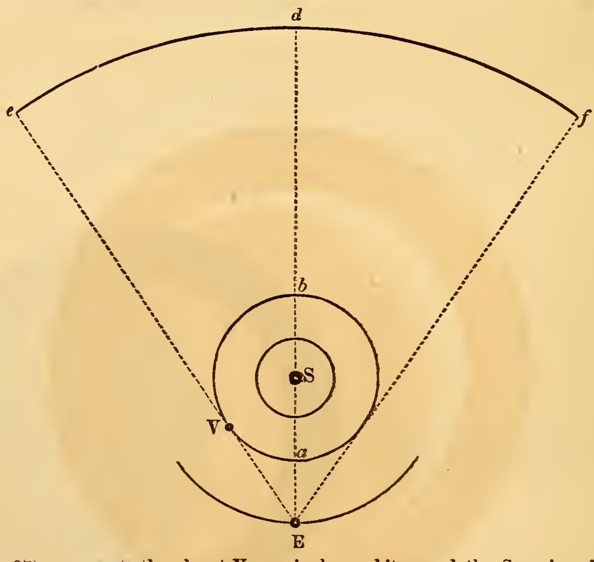
Q. When is only HALF her illuminated disc towards us?

A. At the time of her *greatest elongation*.

Q. What is meant by ELONGATION?

A. The *difference* between the Sun's place and the *geocentric place* of the planet; that is, the angle formed by lines drawn from the centres of the Sun and planet to the centre of the Earth.

Fig. 37.



V (*fig.* 37) represents the planet Venus in her orbit round the Sun, in which she moves through a series of positions, sometimes between the Earth and the Sun, and sometimes beyond the Sun. When at *a*, she is between the Earth, E, and the Sun, S, and is then in her inferior conjunction; and when at *c*, she is at her greatest western elongation, or her greatest angular distance from the Sun towards the west. When at *b*, she is in her superior conjunction; and at V, she is at her greatest angular distance from the Sun towards the east, or at her greatest eastern elongation. When the planet is at *c*, it is seen among the stars at *f*, and the Sun is seen at the same time at *d*; consequently, the angular distance *d f* is the planet's greatest western elongation. In the

same way, at V, the planet appears projected on the sphere of the heavens at *e*; and the angular distance from *d* to *e* is its greatest eastern elongation.

Q. What is meant by CONJUNCTION?

A. The apparent *meeting* of the heavenly bodies.

In the foregoing figure, when the earth is at E, if the planets Mercury or Venus should be *between* the Earth and the Sun, or on the dotted line *a* S, they would be in *inferior* conjunction. But if either of the above-named planets should be on the dotted line *b* S, that is, beyond the Sun, they would then be in superior conjunction.

Q. When Venus is between the Earth and the Sun, which body is she NEAREST to?

A. She is nearer to the *Earth* than to the Sun.

Q. How far is Venus from the Sun?

A. She is about *sixty-eight millions of miles* from the Sun.

Q. When Venus is in INFERIOR CONJUNCTION, how far is she from our Earth?

A. When in inferior conjunction she is *twenty-seven millions of miles* from the Earth.

Q. Does she appear LARGER when in inferior conjunction than when in superior conjunction?

A. She does; because when in superior conjunction she is *one hundred and sixty-three millions of miles* from us.

Q. How much GREATER does the diameter of Venus appear when in inferior than when in superior conjunction?

A. The diameter of Venus appears *more than six times* greater when in inferior than when in superior conjunction.

Fig. 38.

Fig. 38 represents the planet Venus as seen through the telescope when near her inferior conjunction. As Venus is usually invisible when in inferior conjunction, that is, when between us and the Sun, she appears as a slender crescent only immediately *before* and *after* her inferior conjunction, proving conclusively that she is a round opaque body.

Q. Does Venus ever present the appearance of a FULL ORB?

A. She *does;* when in that part of her orbit *beyond the Sun*, as respects the Earth, she appears with a full round disc.

Fig. 39.

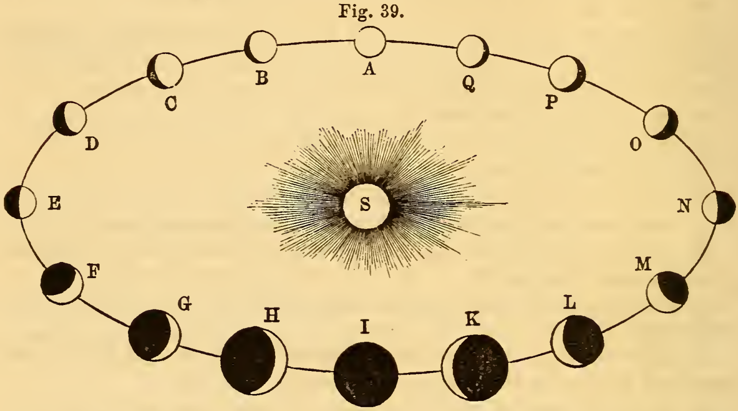


Fig. 39 exhibits the phases of Venus as seen through the telescope. At I, the planet is represented in inferior conjunction, being between the Earth and the Sun. In this position Venus is usually invisible, having her dark side turned towards the Earth. She soon appears after this as a morning star, exhibiting a very slender crescent, which may be seen by the aid of a telescope. As the planet moves on from east to west, the crescent increases, till at N it presents the appearance of a half moon. At this point Venus appears to remain stationary for some time, after which she seems to move from west to east. This is her *direct motion.* As she advances through the positions O, P, and Q, she presents more and more of her enlightened hemisphere, till she arrives at A, where she becomes completely full. At A, Venus is in *superior conjunction,* and at her greatest distance from the Earth. At B, she appears as an evening star, and exhibits a gibbous phase, which increases, till on her arrival at E she again has the appearance of a half moon. From E to I she seems to move from east to west, which is called her *retrograde motion.* From F she assumes again the figure of a crescent, which diminishes in breadth, but increases in extent from horn to horn, until she arrives at I.

Q. What are the DIMENSIONS of the planet Venus?

A. Her diameter is about *seven thousand seven hundred miles*, which is but little less than the diameter of our Earth. (*Note* 9.)

Q. How LONG is Venus in performing her journey round the Sun?

A. She makes one revolution round the Sun in a little more than *two hundred and twenty-four days*, or about *thirty-two* of our weeks.

Q. Then what is the length of Venus's YEAR?

A. About *thirty-two of our weeks.*

Q. If Venus revolves round the Sun in TWO HUNDRED AND TWENTY-FOUR DAYS, why does she apparently remain on the same side of the Sun for the space of more than two hundred and ninety days?

A. Because the Earth moves in her orbit in the *same direction* that Venus moves in hers; but as the earth moves more slowly than Venus, she finally outstrips the Earth, thus making her *synodic* revolution, that is, the period between two conjunctions, to consist of 584 days.

Q. With what VELOCITY does Venus move in her orbit?

A. Venus moves at the rate of *eighty thousand miles an hour* in her journey round the Sun.

Q. Do the planets move with EQUAL velocities?

A. No; the *nearer* a planet is to the Sun, the *greater* is its orbital velocity.

Q. Why do those planets NEAR to the Sun move with greater velocity in their orbits than those which are MORE DISTANT?

A. Because the nearer a planet is to the Sun, the *more powerful* is the Sun's *attraction;* therefore, it must move with proportional velocity to *overcome* that attraction.

Q. Does Venus REVOLVE upon her AXIS as she moves round the Sun?

A. She does. Venus performs one revolution on her axis in about *twenty-three hours and a quarter;* therefore the day on Venus is very little shorter than ours.

Q. What causes the variety of SEASONS?

A. The change of seasons is owing to the *inclination of the axis* of a planet to the plane of its orbit.

Q. Is the axis of Venus INCLINED to the plane of her orbit?

A. Yes; the axis of Venus is inclined $73\frac{1}{2}°$ to the plane of her orbit, while that of the Earth is inclined only about $23\frac{1}{2}°$; so that the *tropics* of Venus are within her *polar circles.*

Q. Explain how the tropics of Venus are WITHIN her polar circles.

A. As the axis of Venus is inclined $73\frac{1}{2}°$ to the plane of her orbit, her tropics must be $73\frac{1}{2}°$ on each side of her equator; that is, to within $16\frac{1}{2}°$ of her poles; and as the polar circles are as far from the poles as the tropics are from the equator, it follows that her polar circles must be within $16\frac{1}{2}°$ of her equator. (*See Note* 10.)

Q. Where are the TROPICS situated?

A. The tropics include that space or part of the sphere called the *torrid zone;* because the Sun is at one time or other perpendicular over every part of it, and *torrifies* or *heats it.*

Q. How is it known that the planets Mercury and Venus revolve in orbits WITHIN the orbit of the Earth?

A. Because they are never seen opposite to the Sun; that is, they are never seen in the *east* when the Sun is in the *west;* nor are they ever on the *meridian* at *midnight.*

Q. Is there any other proof that these planets revolve in orbits NEARER to the Sun than that of the Earth?

A. Yes; they each may sometimes be seen to *pass across* the Sun's disc like a dark spot.

Q. What is the PASSAGE of these planets across the Sun's disc called?

A. It is called a *transit* of the planet.

"*Transit*" is derived from the Latin word *transitus,* which means *passing* or *going over.*

Q. When is Venus a MORNING, and when an EVENING, star?

A. Venus is a *morning star* from inferior to superior conjunc-

tion; and from superior to inferior conjunction she is an *evening star.*

> "Fair morning star
> That leads on dawning day to yonder world
> The seat of Man."

Q. Has Venus any attendant MOON?

A. No moon has ever been discovered as belonging to Venus; but owing to her proximity to the Sun it would be very difficult to see one, if it even exists.

Q. Are Mercury and Venus the ONLY PLANETS nearer to the Sun than the Earth?

A. No other planets have ever been discovered whose orbits are within the orbit of the earth.

CHAPTER IV.

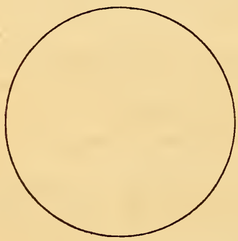
The Earth. ⊕

> "This world
> Poised in the crystal air, with all its seas,
> Mountains, and plains, majestically rolling
> Around its noiseless axis."

Q. What is the EARTH?

A. A *globe* enclosed in an envelope of air, called the atmosphere.

Fig. 40.



The atmosphere which surrounds the Earth is not thicker in proportion to the bulk of our globe than the circular line in the figure, when compared with the space which it encloses, or the down on the skin of a peach, in comparison with the fruit inside.

Q. Of WHAT is the large globe of the Earth composed?

A. It is composed of very *small particles of matter*, which attract each other so strongly, that they cannot be moved about among each other without the aid of some force.

The gravitation of the Earth to the Sun results from the gravitation of all its component parts, which also attract the Sun in proportion to their respective masses.

Q. Of what is the air which surrounds the Earth COMPOSED?

A. It is a gas formed of extremely minute particles of matter floating about freely among each other.

Q. Are the particles which form the air as CLOSELY CONNECTED together as those of solid bodies?

A. No; the particles of gases are not so *compact*, but move freely among each other.

Q. How is it known that the atmosphere is a MATERIAL substance?

A. Sensible *mechanical effects* are produced by its motion and its weight.

Q. What are the mechanical effects produced by its MOTION?

A. The force of the wind drives the sailing ship in its course; for the sails of the ship are as much affected by the material pressure of the wind, as a ball is, when thrown, by the material pressure of the hand.

Q. Is the surface of the Earth SMOOTH?

A. No; it is formed into *elevations and depressions;* but of very trifling extent when compared with the globe itself.

Q. But some MOUNTAINS are very high, and some MINES have been opened to a great depth; do not these produce great irregularity in the Earth's surface?

A. The highest mountain on the Earth is only about five miles above the level of the sea, and the deepest mine hitherto opened does not exceed half a mile; these irregularities are not greater than grains of sand and pin-point scratches on the surface of an artificial globe two feet in diameter.

"These inequalities to us seem great;
But to an eye that comprehends the whole,
The tumour which to us so monstrous seems
Is as a grain of sparkling sand, that clings
To the smooth surface of a sphere of glass;
Or as a fly, upon the convex dome
Of a sublime, stupendous edifice."—LOFFT.

Q. Does the atmosphere occupy ALL the cavities of the Earth's surface?

A. The greatest depressions are filled with *water*, a denser fluid, which flows into them, owing to its greater weight, and thus excludes a great part of the air. These collections of water are called *oceans* and *seas*.

Q. Does any of the water of the ocean ascend into the atmosphere?

A. Portions of the water rise into the air as *vapor*, as far as the highest clouds.

Q. Does any of the atmosphere penetrate into the WATER?

A. Yes; portions of *air* are contained in water. It is the *vapor* of the atmosphere which falls as *rain*.

Q. Is the Earth at REST?

A. No; it is constantly *turning round on its axis* with a uniform motion.

"The globe terrestrial, with its slanting poles,
And all its pond'rous load, unwearied rolls."—BLACKMORE.

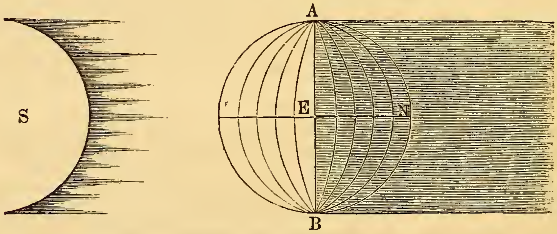
Q. What is the AXIS of the Earth?

A. An *imaginary line* passing through the poles upon which the Earth is supposed to turn.

Q. How is it known that the Earth REVOLVES on its axis?

A. Because the inhabitants on its surface are, by its rotation, carried into the darkness of its own shadow, which produces night; and then into the sunlight, which we call day.

Fig. 41.



Suppose A B to be the Earth, which is an opaque globe; S represents the Sun, N the deep shadow of midnight, and D the time of noonday. If an observer were to be carried from D to E, and then to N, he would pass from noonday to midnight.

Q. How long does the Earth require to perform one COMPLETE REVOLUTION on its axis?

A. *Twenty-three hours, fifty-six minutes, four seconds and one-tenth.* This is called a *sidereal day.*

Q. What is the FORM of the Earth?

A. The Earth has the form of a *sphere,* swelling out in one direction of its circumference, like an orange.

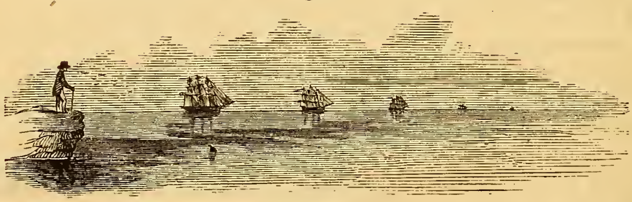
Q. How is the Earth known to be SPHERICAL?

A. Because navigators have *sailed round it,* without materially changing their course; just as a fly may be seen to walk round an orange, returning to the place it set out without retracing its steps.

Q. Is there any OTHER PROOF of the spherical form of the Earth?

A. Yes; the *shadow* which the Earth casts is only such as belongs to spherical bodies.

Fig. 42.



Q. When ships are leaving port, what PART of the vessel first DISAPPEARS?

A. The *hull* first disappears, and finally the topmasts are lost to our view as the ship recedes from the shore.

This is owing to the convexity of the Earth: for although the sea appears level to a person standing on the shore, it is sufficiently curved to conceal the hull of a ship while the topmasts remain in view.

"Behold when the glad ship shoots from the port,
Upon full sail, the hull first disappears,
And then the lower, then the higher sails;
At length the summit of the towering mast
Alone is seen; nor less, when from the ship
The longing sailor's eye, in hope of shore;
For then, from the topmast, though more remote
Than either deck, the shore is first beheld."

Q. What are the POINTS at the EXTREMITIES of the Earth's axis called?

A. They are the *poles.*

Q. Is the Earth COMPLETELY spherical?

A. No; it is an *oblate spheroid,* that is, in the shape of an orange, being a little flattened at the poles.

Q. What part of the Earth PROTRUDES the most?

A. The *equatorial regions,* or that part at and near the equator.

Q. Why are the equatorial regions more PROTUBERANT than any other portions of the Earth?

A. Matter is *heaped up* there by the force of its *rapid motion* on its axis. (*See Note* 11.)

Q. When a wet grindstone is made to revolve quickly, why does the water FLY OFF from its edge?

A. Because the *rapid motion* of the stone increases the *centrifugal force.*

Q. If the motion of the grindstone be LESS RAPID, will the water fly off?

A. No; it will be *heaped up* on its edge, instead of being thrown off.

Q. To what EXTENT does the equatorial portion of the Earth protrude?

A. The breadth of the equatorial diameter is to the breadth of the polar diameter as 299 to 298.

Q. What, then, is the difference IN MILES between the two diameters?

A. The equatorial diameter is *twenty-six miles and a half longer* than the polar diameter.

Q. How is the amount of this difference ascertained?

A. This difference is ascertained by means of the *pendulum.* The pendulum beats faster in proportion to its proximity to the Earth's centre; and the rate of its beating when near the poles shows that it is there the *one two hundred and ninety-eighth part nearer* the Earth's centre than it is at the equator.

Q. Could the DIFFERENCE between the polar and equatorial diameters be discerned by the eye, if the Earth could be viewed from the Moon?

A. No; from that distance the Earth would appear to have a completely *circular outline,* the difference between its polar and equatorial diameters being too insignificant to be detected by the eye.

Q. What is the real SIZE of the Earth?

A. The Earth is about *eight thousand* miles in diameter.

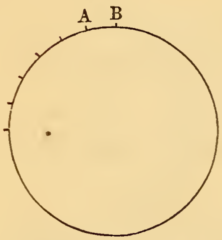
More correctly, it is 7926 miles in diameter.

"Of this dependent universe, our planet is a part so small, that no arithmetician can assign a fraction low enough to express its proportion to the whole."

Q. How is the exact size of the Earth ASCERTAINED?

A. By measuring small and known *proportional parts.*

Fig. 43.



Let the space between A B (fig. 43) be known to be a twenty-fourth part of the circumference of the Earth; and let it be found to measure one thousand miles. Then the whole circumference would necessarily measure twenty-four thousand miles; for it contains twenty-four such intervals.

Q. Has a twenty-fourth part of the Earth's circumference ever been MEASURED?

A. In India, *rather more* than a twenty-fourth part of the Earth's circumference has been measured.

Q. Has the Earth any OTHER MOTION than that of its revolution on its axis, producing day and night?

A. Yes; it revolves round the Sun once in a *year.*

Q. In the annual revolution round the Sun, does the Earth's axis always retain the SAME POSITION?

A. It does; the axis of the Earth always points towards the *same fixed star.*

This problem may easily be solved by observing that any fixed object on the Earth, as the index or gnomon of a sun-dial, always points to the same part or spot in the heavens; whereas, if the position of the Earth's axis were changeable, it would point to different parts of the heavens in the different seasons of the year.

Q. What is the DISTANCE of the Earth from the Sun?

A. About *ninety-five millions of miles.*

Q. Does the Earth always keep at the SAME DISTANCE from the Sun?

A. No; the Earth is *nearer* to the Sun at one part of the year than at any other.

Q. How is it KNOWN that the Earth is nearer to the Sun at one part of the year than at any other?

A. Because the Sun appears *larger* sometimes than at others, and all distant bodies appear of a larger size when brought nearer to the eye.

Q. When has the Sun the LARGEST apparent size?

A. About the *beginning of December.*

Q. When has the Sun the SMALLEST apparent size?

A. About the *first of July;* and as it is not probable that the Sun changes his real size periodically, the observed change of his apparent size can only arise from an actual change of distance.

Q. How can the exact BREADTH of the Sun's disc be ascertained?

A. By observing the *time* it requires to pass across a thread placed perpendicularly in the focus of the eye-glass of a telescope.

Q. How much FARTHER is the Earth from the Sun in July than in December?

A. Nearly *three millions of miles* farther from the Sun in July than December.

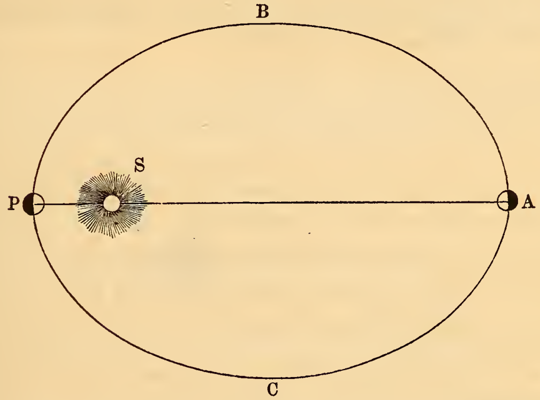
Q. What is the FORM of the path which the Earth describes round the Sun?

A. Its form is that of an *ellipse.* (*See Note* 12.)

Q. In what PART of the Earth's orbit is the Sun placed?

A. The Sun occupies one of the *foci.*

Fig. 44.



Let A B P C represent the orbit of the Earth, and S the Sun. It will be seen that the Sun is not in the *centre* of the elliptical orbit, but in one of the *foci.* It must be remembered that the ellipse delineated in the figure is not sufficiently circular to represent the orbit of the Earth, which is so slightly elliptical that, were it drawn in true proportions, its ellipticity would not be discernible by the eye.

Q. What is meant by PERIHELION?

A. That point in a planet's orbit *nearest to the Sun.*

Q. What is meant by APHELION?

A. That point in a planet's orbit *farthest from the Sun.*

Q. When the Earth is approaching its perihelion, why does it not PURSUE ITS COURSE in a straight line till it comes in actual contact with the Sun?

A. Because as the Earth approaches the Sun his attraction is *more powerful*, and thus causes it to *move faster.*

Q. How does the increased motion of the Earth PREVENT it from coming in contact with the Sun?

A. By conferring upon it increased momentum, its *projectile* or *centrifugal force* is increased.

When the Earth is at the point B, (*fig.* 44,) its velocity increases until it arrives at its perihelion P. At this point its increased momentum overcomes the Sun's attraction, and it pursues its course through C to A, its aphelion, where its motion is the slowest. At A the Sun's attraction overcomes the projectile force, and it is drawn again towards that luminary with increased momentum, till it arrives at its perihelion at P.

Q. Why does the Earth begin to APPROACH the Sun when it has arrived at aphelion, or that point in its orbit farthest from that luminary?

A. Because then the Sun's *attraction preponderates* over its momentum.

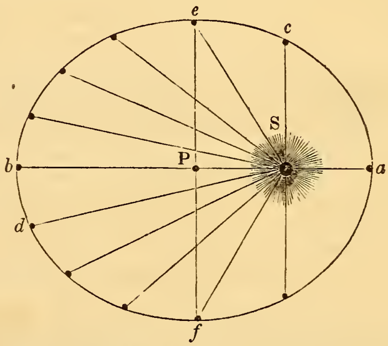
Q. Why does the Earth begin to RECEDE from the Sun when it has reached its perihelion, or that point in its orbit nearest to that luminary?

A. Because then its momentum *overcomes* the Sun's attraction.

Q. How much FASTER does the Earth move when in perihelion than when it is in aphelion?

A. It moves so much faster in perihelion, that a line drawn connecting the centre of the Earth with the centre of the Sun, would pass through the *same quantity of superficial space*, and in the same time, that another line would do, drawn from the centre of each, when the Earth is in aphelion.

Fig. 45.



In the above figure let S *a* represent a line connecting the centres of the Earth and Sun when the Earth is at perihelion, or her least distance from the Sun; and let S *b* represent a line connecting their centres when the Earth is at aphelion, or her greatest distance from the Sun; then if the contents of the angular space *b* S *d* were exactly equal to the contents of the differently shaped angular space *a* S *c*, then *b d* would represent the portion of its orbit through which the Earth would travel in some given time, say a month, when at its remotest distance, and *a c* the portion of its orbit through which it would travel in a month when at its nearest distance; for the long line S *b* and the short line S *a* both sweep over the same superficial space or area, in the same given time. The Earth, therefore, moves much faster from *a* to *c* than from *b* to *d*. (*See Note* 13.)

Q. Why does the Earth MOVE ROUND the Sun?

A. Because it is impelled by *two forces*, which, combined together, drive it round the Sun.

Q. What are these two forces CALLED?

A. The projectile, or *centrifugal* force belonging to the Earth is that which impels the earth to fly from her orbit; and the attraction of gravitation, or *centripetal* force, which is a power seated in the Sun, is that which gives the Earth the tendency to approach the Sun. Thus the two forces combined retain the Earth in her orbit, and cause it to move round the Sun.

Q. In what DIRECTION does the power seated in the Sun influence the Earth?

A. The solar power draws the Earth *towards the Sun.* The Sun's mass attracts the Earth's mass.

"*Mass*" means the entire amount of matter contained in a body.

Q. What is that POWER called which is seated in the Sun's mass?

A. It is called *centripetal force*, or the *attraction of gravitation.*

It is a universal law, that all ponderable bodies have a mutual attraction in proportion to their mass.

Q. Does the Earth exercise an ATTRACTIVE INFLUENCE over other bodies?

A. It does. The Earth attracts the *Sun* and *Moon*, as well as suffers attraction by them. It also attracts *all bodies* on its surface.

Q. How is the Earth's ATTRACTIVE INFLUENCE most plainly shown?

A. By its *retaining* small bodies upon its surface with a certain amount of force.

Q. Why cannot we lift a stone or other body without exerting some FORCE?

A. Because we must overcome the *resistance* caused by the *attraction* of the Earth's mass for the mass of the stone.

Q. What is this RESISTANCE called?

A. It is called *weight* or *gravity.*

Q. Why does not the Earth FALL towards the Sun, as a stone would fall towards the Earth?

A. Because the influence of that power called the *centrifugal force*, prevents the Earth from falling to the Sun.

Q. What is the NATURE of that power called centrifugal force?

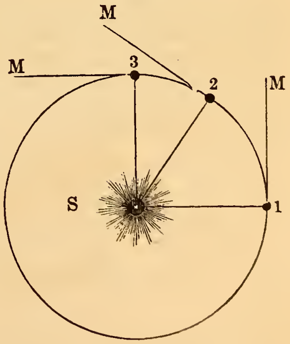
A. It is the *moving* or *projectile power*, acting upon the Earth in a different direction from the solar influence.

The moving power which a ball possesses, after it has been thrown or struck by the hand, is its *projectile force.*

Q. In what DIRECTION does the projectile force of the Earth impel it?

A. It impels it in a direction very nearly at *right angles* with that line along which the Sun's attraction acts.

Fig. 46.



Suppose S (*fig.* 46) to be the Sun, and 1 the Earth in one part of her orbit. Then the Earth's projectile or centrifugal force impels it towards M, along the line 1 M; and this crosses at right angles the line 1 S, which represents the direction from which the Sun's attraction acts. The primary impulse which made the Earth a moving body must have been exerted in this way, directly at right angles with the line leading from the Earth to the Sun.

Q. When two forces impel a body in different directions, WHAT COURSE does the moving body pursue?

A. It moves in a line *intermediate* to those directions. It obeys both forces by taking a *middle course* between them.

Q. Since the Sun attracts the Earth towards itself, while the Earth's projectile force impels it in a direction at right angles with the line leading towards the Sun, in what DIRECTION does the Earth really move?

A. It obeys *both forces,* and moves in a direction intermediate to the lines in which they act.

In *fig.* 46, page 49, suppose the Earth to be at 1 in her orbit, and to receive an impulse in the line 1 M, at the same time that she is drawn towards the Sun S, in the line 1 S; she would in that case take the intermediate course between them, and arrive at 2.

Q. Does the Earth move in a STRAIGHT LINE under the combined influences of the two forces?

A. No; it moves in a curved line everywhere surrounding the Sun.

Q. Why does the Earth move round the Sun in a CURVED path?

A. Because the *momentum* of its own motion, and the *attraction* of the Sun, are continued forces, constantly acting in new directions in consequence of the Earth's motion in her orbit.

The curved line is the only one that can be always intermediate to the new directions of these shifting forces. Thus, in *fig.* 46, the lines 1 M, 2 M, 3 M, show the altered directions in which the Earth's projectile force acts as it moves round in its curve from 1 to 2 and 3, while the lines 1 S, 2 S, 3 S, show the altered directions of the Sun's attraction during the progress. The circular line, 1, 2, 3, shows how the actual path of the Earth is curved, in obedience to the change of the direction of the two impelling forces. The same thing occurs when a sling is made to whirl round the head. The projectile force of the whirling stone always inclines it to fly off in some line corresponding to 1 M, 2 M, 3 M of the figure; while the string always holds it in some line corresponding to 1 S, 2 S, 3 S. The path pursued is the circular one, which is always intermediate to the shifting directions in which the two forces act; and the moment the stone is freed from the influence of one of these forces, the holding-in power of the string for instance, it obeys the other force, and flies off in a direction at right angles to the string.

Q. What is meant by MOMENTUM?

A. The onward impulse, or *force of motion* of a body.

Q. From what SOURCE does the Earth get its momentum?

A. The Earth has received its motion from the *hand* of the *Creator.* Its momentum is dependent on the velocity with which it was launched into space.

The case is the same, whether the Earth's motion was primarily communicated to it by the Creator, or was transferred therefrom by some intermediate agency. The same conclusion is arrived at in either case. It does not matter whether the ball is said to be impelled by a bat, or by the hand, because in both instances it is understood that the motion is given to the ball by the player.

Q. To what is the MOMENTUM of the Earth's motion due?

A. The momentum of the Earth's motion is due to the amount of its mass, as well as to the velocity of its motion.

Q. What is the VELOCITY with which the Earth moves in her orbit?

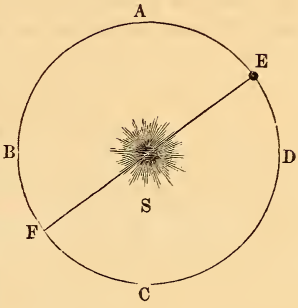
A. It moves at the rate of about *sixty-eight thousand miles an hour.*

Q. How is it KNOWN that the Earth moves with this velocity?

A. The Earth's orbit is a curve, whose mean distance from the

Sun is about ninety-five millions of miles. It revolves in this orbit in three hundred and sixty-five days; therefore its hourly motion may easily be found.

Fig. 47.



In the annexed figure, let A B C D represent the orbit of the Earth, which is not, however, a *complete* circle. The line S E will indicate the distance of the Earth from the Sun. Now, as S E, which is ninety-five millions of miles, is only *one-half* of the diameter of the Earth's orbit, the whole diameter must be *twice* ninety-five millions of miles, or one hundred and ninety millions. The diameter F E, therefore, represents one hundred and ninety millions of miles. The circumference of a circle is equal to its diameter multiplied by 3·14. Consequently, the circumference of the Earth's orbit is a little more than five hundred and ninety-six millions of miles. At an even rate of sixty-eight thousand miles per hour, the Earth would accomplish this journey in eight thousand seven hundred and sixty-four hours; and there are eight thousand seven hundred and sixty-six hours in a year. This calculation is deemed sufficiently accurate to elucidate the subject without taking any fractions into the account.

Q. What would be the result of INCREASING the velocity of the Earth's motion?

A. The Earth would *move farther* from the Sun under the influence of the increased momentum.

Q. What would be the result of DIMINISHING the velocity of the Earth's motion?

A. The Earth would move *nearer* and *nearer* to the Sun, because the diminished momentum would not then be sufficient to prevent the Sun from attracting the Earth to itself.

Q. Why is it, then, that the Earth MOVES EVENLY in its curved orbit, neither falling towards the Sun, nor flying away from it?

A. It is because the Earth's *mass*, and the velocity and direction of the projectile force primarily impressed upon it, are so exactly adapted to the Sun's mass and attractive power, that neither the momentum of the Earth, nor the attraction of the Sun, can ever neutralize or overbalance each other.

Thus wonderfully are all the planets sustained in space. The still more enormous mass of the Sun attracts them; but they are already moving so fast that their own momentum prevents them from obeying the Sun's attraction. The attraction of the Sun, therefore, merely causes the Earth to move in a curved line forever returning into itself, or very nearly so; and that curved line becomes its fixed orbit.

CHAPTER V.

Exterior Planets.

"Give me the ways of wandering stars to know,
The depths of Heaven above, and Earth below."

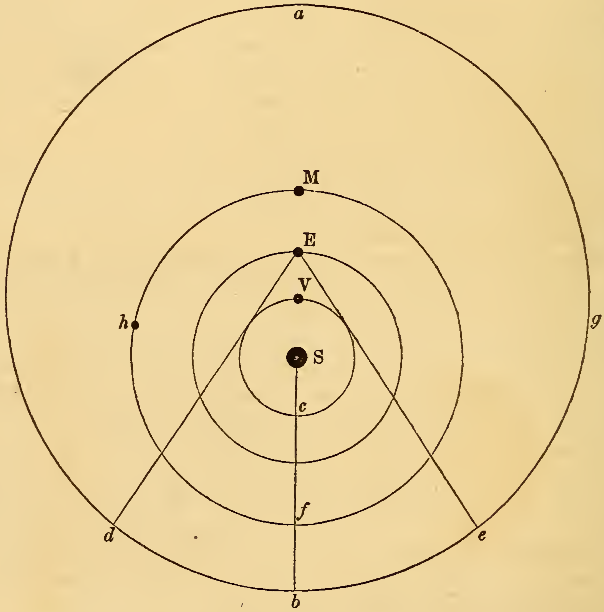
Q. What are the EXTERIOR planets?

A. They are those planets whose orbits are *exterior* or *outside* of the orbit of the Earth.

Q. How is it known that the orbits of these planets are EXTERIOR to the orbit of the Earth?

A. Because they are never seen to cross the Sun's disc, as Mercury and Venus do; and they may be seen at times in that part of the heavens *directly opposite* to the Sun; that is, when the Sun is setting, they may sometimes be seen rising, or they may be seen sometimes on the *meridian* at *midnight.*

Fig. 48.



Let E represent the Earth, *a d b e g* the concave surface of the heavens surrounding it, M the position of Mars in its orbit surrounding that of the Earth E, and S the position of the Sun. From the Earth, Mars is seen among the fixed stars at *a*, and the Sun at *b*, points which are directly opposite to each other; consequently, Mars is then on the meridian at midnight. Now, let V represent Venus in her orbit, surrounded by the Earth's orbit; it is plain that the Sun and Venus can never be seen in opposite parts of the heavens. They would appear together at *b*, both when the planet Venus is at V and *c* in its orbit, and at all other times it would appear to oscillate with regard to the Sun's place, never, however, getting farther from him than the distance from *b* to *d*, or from *b* to *e*; therefore, Venus can never be seen on the meridian at midnight.

Q. What are the NAMES of the exterior planets?

A. *Mars*, the *Asteroids*, *Jupiter*, *Saturn*, *Uranus*, and *Neptune.*

SECTION I.

Mars. ♂

Q. What is the NAME of that planet fourth in order from the Sun, and next beyond the orbit of the Earth?

A. It is known as the planet *Mars.*

"See Mars, alone, runs his appointed race,
And measures out exact the distant space;
Nor nearer does he wind nor farther stray,
But finds the point where first he rolled away."—BAKER.

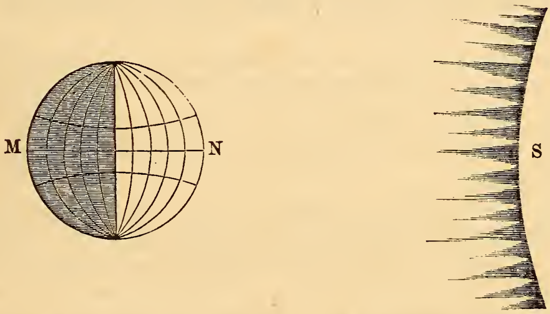
Q. Explain why Mars may be sometimes seen on the MERIDIAN at MIDNIGHT.

A. As his orbit is *exterior* to that of the Earth, he may sometimes be *opposite* to the Sun; that is, on the meridian at midnight, or rising in the east when the Sun is setting in the west.

Q. Can you explain WHY a planet is opposite to the Sun when it is on the meridian at midnight?

A. Yes; when the Sun is on the meridian, it is noon, and the point immediately opposite to it must be the point of midnight.

Fig. 49.



Thus, to a spectator situated at N, (*fig.* 49,) it would be noon; and when he would be carried by the Earth's motion on her axis round to M, it would be midnight, in which situation the point overhead would be opposite to the Sun.

Q. How long does Mars require to perform ONE REVOLUTION round the Sun?

A. Mars revolves round the Sun in about six hundred and eighty-seven days, or very nearly twenty-three of our months.

Q. What constitutes the LENGTH of a planet's year?

A. The time it requires to perform *one revolution* in its orbit.

Q. How LONG, then, is the year of Mars?

A. *Twenty-three months*, or nearly two of our years.

Q. What is the DISTANCE of Mars from the Sun?

A. Mars revolves about the Sun at a mean distance of *one hundred and forty-two millions of miles.*

Q. What is the DISTANCE of Mars from the EARTH?

A. Mars is at *various distances* from the Earth in various parts

of his orbit. Sometimes he is only about *fifty millions of miles* from us, and at others as far distant as *two hundred and forty millions of miles.*

Q. Explain this.

A. When Mars is at M, (*fig.* 48,) and the Earth at E, the two bodies are only separated by the space of a little less than fifty millions of miles; because the Earth is ninety-five millions of miles from the Sun, and Mars is one hundred and forty-two millions of miles distant from him. But when he is at *f*, and the Earth at E, the two bodies are separated by the interval E *f*, which is greater than the distance M E by the entire breadth of the Earth's orbit, which is one hundred and ninety millions of miles. So that when Mars is at *f*, and the Earth at E, he is two hundred and forty millions of miles from the Earth.

Q. Does Mars always appear of the SAME SIZE?

A. No; when opposite to the Sun, as at M, (*fig.* 48,) he appears *much larger* than when he is at *f*, beyond the Sun.*

Q. Does he appear BRIGHTER when he appears the largest?

A. Yes; when in opposition, that is, when he is on the meridian at midnight, he appears much *brighter*, because he is then *nearer* to us.

Q. Does Mars RETURN in opposition to the Sun again in six hundred and eighty-seven days, which is the time he requires to perform one revolution round that luminary?

A. No; for while Mars goes *once* completely round in his orbit, the Earth performs one revolution round the Sun, and the greater *part of another.*

Q. How MANY DAYS, then, are required for Mars to be in opposition to the Sun?

A. About seven hundred and eighty days are required for Mars to be again in opposition, in which time the Earth will have performed rather more than two revolutions round the Sun.

Q. What is the REAL SIZE of the planet Mars?

A. Mars is about *four thousand one hundred miles* in diameter; which is but little more than half the diameter of the Earth?

Q. Does Mars assume the same variety of PHASES as Mercury and Venus?

A. No; Mars never appears like a crescent, because he can never be so placed with regard to the Earth and Sun that less than half of his illuminated hemisphere is turned towards the Earth.

When Mars is at M, (*fig.* 48,) and the Earth at E, his illuminated hemisphere is turned towards the Earth as well as towards the Sun. But when Mars is at *h*, a little more than half the illuminated hemisphere is turned towards the Earth, and the planet appears *gibbous;* that is, it has one of its illuminated edges flatter than the other, like the Moon three or four days before and after the full.

---

* The greatest and least apparent diameters of Mars are 18″ and 4″ of angular measurement.

Q. How does Mars APPEAR when viewed through the TELESCOPE?

A. When Mars is viewed through a telescope at the time of his nearest approach to the Earth, his disc is found to be *variegated* by patches of different shades of color and brilliancy. His general appearance is that of a dusky red color.

Fig. 50.

Q. Have any OTHER peculiarities of Mars been revealed by the telescope?

A. Brilliant *white spots* surround each of his poles when it is again turned towards the Sun, after having been a long time deprived of his beams. These spots diminish gradually under the influence of the solar heat.

Q. What are these WHITE SPOTS supposed to be?

A. They are supposed to be owing to an accumulation of *snow.*

Cassini and Sir William Herschel believed they could detect indications of the presence of a dense atmosphere round the planet Mars, but more recent observations, and particularly those of Sir James South, disprove its existence.

Q. Does Mars REVOLVE on his AXIS?

A. Yes; Mars revolves on his axis in a little more than *twenty-four hours and a half*, which makes his day only half an hour longer than ours.

Q. Is the axis of Mars, like that of our Earth, INCLINED to the plane of his orbit?

A. Yes; the axis of Mars is *inclined* 30° 18′ to the plane of his orbit.

Q. What EFFECT is produced on a planet by the inclination of its axis?

A. The inclination of a planet's axis causes the *variety of seasons.*

Q. Are the seasons of Mars SIMILAR to those on the Earth?

A. They are; because his axis has nearly the same inclination to his orbit as that of the Earth.

SECTION II.

Asteroids.

Astronomers are now agreed to affix to each of these planets the sign of a small circle, with a number within it, in the order of their discovery.

"There's not the smallest orb which thou behold'st
But in his motion like an angel sings,
Still quiring to the young-eyed cherubims.
Such harmony is in immortal souls;
But whilst this muddy vesture of decay
Doth grossly close it in, we cannot hear it."—MERCHANT OF VENICE.

Q. What is the next planet BEYOND Mars?

A. There is a *series* of *very small planets*, which revolve in orbits not very distant from each other, and beyond the orbit of the planet Mars.

Q. What are these small planets CALLED?

A. They are called *Asteroids*, or *Ultra Zodiacal Planets.*

Q. How MANY Asteroids are there, and what are their names?

A. The number of Asteroids now known amounts to eighty-one. Their names, the dates of their discovery, and discoverers, are as follows:

Name.	Date of Discovery.	Discoverer.	Period of Sidereal Revolution, in days.
1. Ceres	1801, January 1	Piazzi	1681.
2. Pallas	1802, March 28	Olbers	1684.
3. Juno	1804, September 1	Harding, Bremen	1592.
4. Vesta	1807, March 29	Olbers, Bremen	1325.
5. Astraea	1845, December 8	Hencke, Driesen, (Prussia)	1511.
6. Hebe	1847, July 1	Hencke, Driesen, (Prussia)	1380.
7. Iris	1847, August 13	Hind, London	1346.
8. Flora	1847, October 18	Hind, London	1193.
9. Metis	1848, April 25	Graham, Sligo	1347.
10. Hygieia	1849, April 12	De Gasparis, Naples	2043.
11. Parthenope	1850, May 11	De Gasparis, Naples	1402.
12. Victoria	1850, September 13	Hind, London	1301.
13. Egeria	1850, Novimber 2.	De Gasparis, Naples	1511.
14. Irene	1851, May 19	Hind, London	1518.
15. Eunomia	1851, July 29	De Gasparis, Naples	1570.
16. Psyche	1852, March 17	De Gasparis, Naples	1826.
17. Thetis	1852, April 17	Luther, Bilk (Dusseldorf)	1420.
18. Melpomene	1852, June 24	Hind, London	1270.
19. Fortuna	1852, August 22	Hind, London	1393.
20. Massalia	1852, September 19	De Gasparis, Naples	1366.
21. Lutetia	1852, November 15	Goldschmidt, Paris	1388.
22. Calliope	1852, November 16	Hind, London	1812.
23. Thalia	1852, December 15	Hind, London	1556.
24. Themis	1853, April 5	De Gasparis, Naples	2034.
25. Phocea	1853, April 7	Chacornac, Marseilles	1359.
26. Proserpine	1853, May 5	Luther, Bilk	1581.
27. Euterpe	1853, November 8.	Hind, London	1314.
28. Bellona	1854, March 1	Luther, Bilk	1689.
29. Amphitrite	1854, March 1	Marth, London	1492.
30. Urania	1854, July 22	Hind, London	1329.
31. Euphrosyne	1854, September 1.	Ferguson, Washington	2048.
32. Pomona	1854, October 26	Goldschmidt, Paris	1520.
33. Polyhymnia	1854, October 28	Chacornac, Paris	1778.
34. Circe	1855, April 6	Chacornac, Paris	1609.
35. Leucothea	1855, April 19	Luther, Bilk	1908.
36. Atalanta	1855, October 5	Goldschmidt, Paris	1666.
37. Fides	1855, October 5	Luther, Bilk	1569.
38. Leda	1856, January 12	Chacornac, Paris	1657.
39. Laetitia	1856, February 8	Chacornac, Paris	1684.
40. Harmonia	1856, March 31	Goldschmidt, Paris	1247.
41. Daphne	1856, May 22	Goldschmidt, Paris	1779.
42. Isis	1856, May 23	Pogson, Oxford	1392.
43. Ariadne	1857, April 15	Pogson, Oxford	1195.
44. Nysa	1857, May 27	Goldschmidt, Paris	1379
45. Eugenia	1857, June 27	Goldschmidt, Paris	1640.
46. Hestia	1857, August 16	Pogson, Oxford	1470.

Name.	Date of Discovery.	Discoverer.	Period of Sidereal Revolution, in days.
47. Melete	1857, September 9.	Goldschmidt (Paris), & Schubert (St. Petersburg)	1529.
48. Aglaia	1857, September 15	Luther, Bilk	1788.
49. Doris	1857, September 19	Goldschmidt, Paris	1998.
50. Pales	1857, September 19	Goldschmidt, Paris	1980.
51. Virginia	1857, October 4	Ferguson, Washington	1577.
52. Nemausa	1858, January 22	Laurent, Nimes (France)	1330.
53. Europa	1858, February 6	Goldschmidt, Paris	1993.
54. Calypso	1858, April 4	Luther, Bilk	1543.
55. Alexandra	1858, September 10	Goldschmidt, Paris	1629.
56. Pandora	1858, September 10	Searle, Albany, New York	1674
57. Muemosyne	1859, September 22	Luther, Bilk	2049.
58. Concordia	1860, March 24	Luther, Bilk	1619.
59. Olympia	1860, September 12	Chacornac, Paris	1633.
60. Echo	1860, September 15	Fergusou, Washington	1352.
61. Danae	1860, September 19	Goldschmidt, Paris	1902.
62. Erato	1860, September 14	Förster, Berlin	2023.
63. Ausonia	1861, February 10.	De Gasparis, Naples	1356.
64. Angelina	1861, March 4	Tempel, Marseilles	1601.
65. Maximiliana	1861, March 8	Tempel, Marseilles	2343.
66. Maia	1861, April 9	Tuttle, Cambridge, Massachusetts	1588.
67. Asia	1861, April 17	Pogson, Madras	1375.
68. Hesperia	1861, April 29	Schiaparelli, Milan	1893.
69. Leto	1861, April 29	Luther, Bilk	1688.
70. Panopea	1861, May 5	Goldschmidt, Chatillon (Paris)	1557.
71. Niobe	1861, August 13	Luther, Bilk	1671.
72. Feronia	1862, February 12.	Peters (Clinton, New York) & Safford (Washington)	1148.
73. Clytie	1862, April 7	Tuttle, Cambridge, Massachusetts	1590.
74. Galatea	1862, August 29	Tempel, Marseilles	1509.
75. Eurydice	1862, September 22	Peters, Clinton, New York	1590.
76. Freya	1862, October 21	D'Arrest, Copenhagen	2080.
77. Frigga	1862, November 12	Peters, Clinton, New York	1360.
78. Diana	1863, March 15	Luther, Bilk	Not determined.
79. Eurynome	1863, September 19	Watson, Ann Arbor, America	Not determined.
80. Sappho	1864, May 3	Pogson, Madras	Not determined.
81. Terpsichore	1864, September 30	Tempel, Marseilles	Not determined.

Q. In what way do the Asteroids DIFFER from the other members of the planetary system?

A. They differ—

1. In point of *size;* the largest of them being only a few *hundred miles* in diameter; and

2. Their orbits are generally much more *inclined* to the *plane of the ecliptic* than the other planets.

Q. What is the DISTANCE of the Asteroids from the Sun?

A. They are all situated at the distance of from *two hundred to three hundred millions of miles* from the Sun, and between the orbits of Mars and Jupiter. (*See Note* 14.)

They are situated in a belt or zone only about *one hundred millions of miles* in width.

Q. What is the FORM of the orbits in which the Asteroids revolve round the Sun?

A. They revolve in *ellipses.* (*See Note* 15.)

Q. Are the Asteroids visible to the NAKED EYE?

A. The greater part of them are *invisible* without the aid of a *telescope.*

Q. In what PART of the heavens are the planetary bodies to be seen?

A. All the planets, except some of the Asteroids, are to be found in the *Zodiac*, a belt or zone extending 8° on each side of the ecliptic.

Q. Why are some of the Asteroids found BEYOND the limits of the Zodiac?

A. Because their orbits are so much *inclined* to the orbit of the Earth.

Q. How LONG are the Asteroids in performing a journey round the Sun?

A. As far as is now known, they perform their revolutions in from about *three to five years.*

SECTION III.

Jupiter. ♃

"More yet remote from day's all-cheering source,
Vast JUPITER performs his constant course;
Four friendly moons, with borrowed lustre rise,
Bestow their beams benign, and light his skies."

Q. What is the NEXT PLANET beyond the Asteroids?

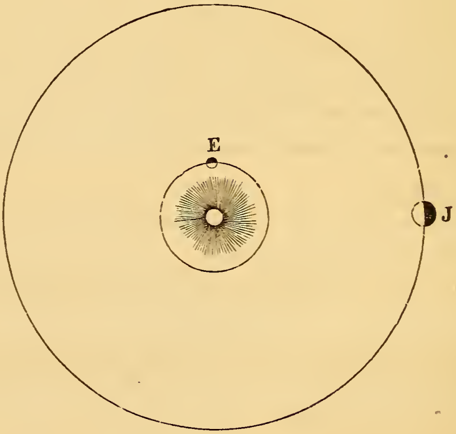
A. The planet Jupiter.

Q. How is it KNOWN that Jupiter is FARTHER from the Sun than Mars?

A. The illuminated disc of Jupiter never *perceptibly* assumes the *gibbous* form which may be observed in the planet Mars.

The orbit in which Jupiter moves is so much more vast than that of our Earth, that the very trifling portion of the planet's hemisphere which is turned away from the Sun can never be distinguished by a spectator on the Earth.

Fig. 51.



In the accompanying figure, let E represent the Earth in her orbit, and J the planet Jupiter. It will be seen that the illuminated half of Jupiter's sphere will always be turned towards us in every part of his orbit; consequently, he can never present the various phases of Venus, nor appear gibbous like Mars.

Q. How FAR is Jupiter from the Sun?

A. Jupiter is about *four hundred and ninety-four millions of miles* from the Sun.

Q. As Jupiter is so much more distant than Mars, how is it that he appears so much more BRIGHT and CONSPICUOUS?

A. Because Jupiter is a *much larger* body than Mars.

Jupiter's diameter is more than twenty times greater than the diameter of Mars; although so much more remote, he always presents a disc nearly six times greater than the mean apparent diameter of Mars.

Q. What is the REAL SIZE of Jupiter?

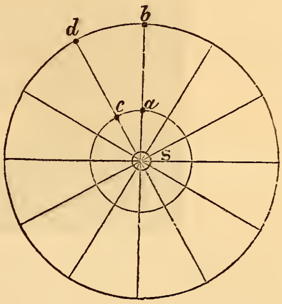
A. Jupiter, the largest planet of our system, is about *eighty-nine thousand miles* in diameter.

It would require nearly 1300 globes of the size of our Earth to make one of the bulk of Jupiter. A railway carriage, travelling at the rate of 33 miles an hour, would travel round the Earth in a month, but would require more than eleven months to perform a journey round Jupiter!

Q. How long does it take Jupiter to make ONE REVOLUTION round the Sun?

A. Jupiter moves round the Sun in a little less than *twelve years;* or, more properly, in *eleven years, ten months, and seventeen days.*

Fig. 52.



Jupiter is seen in that part of the heavens which is opposite to the Sun (that is, on the meridian at midnight) once in every interval of thirteen months and nearly three days. This is because when the Earth has completed one revolution, Jupiter has advanced only a twelfth part toward the completion of his journey round the Sun. In the diagram, S represents the Sun, *a* the Earth in her orbit, and *b* Jupiter in his orbit, on a given day, say the first of January. It will be seen that Jupiter is directly opposite to the Sun with regard to the Earth. Now, on the first of January of the following year, the Earth will have arrived again at *a*, after having completed one revolution; but as Jupiter requires nearly twelve years to perform his journey round the Sun, he will only have advanced one-twelfth part of the circle in that time; that is, from *b* to *d*. But as the Earth passes over the twelfth part of her orbit in one month, at the expiration of a year and one month, that is, thirteen months, she will have arrived again at *c*, which is in the same situation with regard to Jupiter that she occupied when at *a*. Of course this is not an *exact* calculation, as the days, and fractions of days, are not taken into the account.

Q. Does Jupiter ROTATE on his axis as he advances in his orbit round the Sun?

A. Jupiter rotates on his axis once in *nine hours and fifty-six minutes.*

Q. What is, then, the length of a DAY AND NIGHT on the planet Jupiter?

A. Nearly *ten hours*, or, more properly, *nine hours and fifty-six minutes.*

Q. How long, then, do its inhabitants enjoy the LIGHT of the Sun? that is, how long is it from sunrise to sunset?

A. Not quite *five hours.*

On account of the vast size of Jupiter, all places at his equator are carried round by his diurnal motion at the rate of four hundred and sixty-five miles per minute. On the equatorial surface of the Earth, the diurnal motion is only about seventeen miles in a minute.

Q. Is Jupiter a PERFECT SPHERE?

A. No; Jupiter, like the Earth, is *not* a perfect sphere, but *flattened at the poles.*

Q. What CAUSES Jupiter to be flatter at the poles than at the equator?

A. The *great velocity* with which he *revolves* on his axis.

Q. What is the DIFFERENCE between the equatorial and polar diameters of Jupiter?

A. Jupiter measures nearly *six thousand miles more* through his equator than through his poles.

Q. Is this difference of length between the polar and equatorial diameters of Jupiter PERCEPTIBLE TO THE EYE?

A. It is perceptible when the planet is *viewed through a good telescope.*

Q. What OTHER APPEARANCES does the telescope reveal on the disc of Jupiter?

A. The telescope shows the disc of Jupiter crossed transversely by belts of comparative shade.

Fig. 53.

The disc of Jupiter is an exceedingly interesting object, when viewed with the aid of a telescope, on account of its size and subdued lustre. It has the appearance of being surrounded by an envelope of reflective clouds drifted into transverse streaks. The long dark belts are portions of the body of the planet, seen through transparent parts of the atmosphere, where the clouds have separated. The belts frequently change their form, indicating changes in the atmospheric conditions of the planet. These belts were discovered by G. Fontana, an Italian astronomer, in the latter half of the seventeenth century.

In May, 1850, Professor Schumacher, of Altona, observed four or five white spots on one of Jupiter's belts. He says—"The white spots are most remarkable. They are all perfectly round, distinct, and bright. The largest spot is as distinct and well-defined as the disc of a satellite appears in a nine-foot reflector. They are striking phenomena. The spots keep their relative positions as they are carried along by Jupiter's rotation, and there are no other similar spots on his disc."—*Ast. Journal,* vol. i. p. 77.

Q. Does the telescope reveal any OTHER APPEARANCES about Jupiter?

A. Yes; by means of a telescope of moderate power *attendant moons or satellites* may be seen.

Jupiter's satellites are to him what our Moon is to the Earth.

Q. How MANY moons has Jupiter?

A. Jupiter has *four moons.*

Q. Is the axis of Jupiter INCLINED to the plane of his orbit?

A. The axis of Jupiter is *nearly perpendicular* to the plane of his orbit, being inclined to it about 3° 5′.

The Sun is always within 3° 5′ of Jupiter's equator, consequently his torrid zone is only 6° 10′ in width, and his polar circles are only 3° 5′ from his poles; so that his torrid and frigid zones are extremely narrow, while his temperate zones occupy the greater portion of his sphere.

As the Sun is always vertical near Jupiter's equator, his days and nights are nearly always of the same length, except at his poles, which have alternately six years day and six years night.

Q. What is the QUANTITY of light and heat which Jupiter receives from the Sun as compared with that received by our Earth?

A. Jupiter receives only *one twenty-seventh* as much light and heat as we do on the Earth.

Q. Explain this.

A. Jupiter is four hundred and ninety-four millions of miles from the Sun, and the Earth is ninety-five millions of miles from that great luminary. It will be found that the distance of Jupiter, divided by the Earth's distance, will be equal to 5·2, which is the number of times Jupiter's distance from the Sun is greater than that of the Earth. Therefore, the difference of heat received at the planet Jupiter must equal the square of 5·2, or a little more than twenty-seven times *less* than the quantity received at the Earth.

But the atmosphere of Jupiter may be of such a nature, that although his inhabitants receive less solar heat than we do, yet the temperature of the planet may be as high as ours.

SECTION IV.

Saturn. ♄

"Last outmost Saturn walks his frontier round,
The boundary of worlds, with his pale moons
Faint glimmering through the gloom which night has thrown
Deep dyed and dead o'er this chill globe forlorn;
An endless desert, where extreme of cold
Eternal sits, as in his native seat,
On wintry hills of never-thawing ice.
Such SATURN'S earth; and even here the sight
Amid these doleful scenes new matter finds
Of wonder and delight; a MIGHTY RING."

Q. What is the NAME of the planet next beyond Jupiter in our system?

A. *Saturn.*

Q. How FAR is Saturn from the Sun?

A. About *nine hundred millions of miles.*

Q. What is the REAL SIZE of Saturn?

A. Saturn's sphere is about *seventy-nine thousand miles* in diameter, which is about *ten times* greater than the diameter of the Earth.

Q. Does Saturn ROTATE on its axis as it revolves round the Sun?

A. Yes; the sphere of Saturn makes one revolution on its axis every *ten hours and a half.*

Saturn's day is therefore about half an hour longer than that of Jupiter.

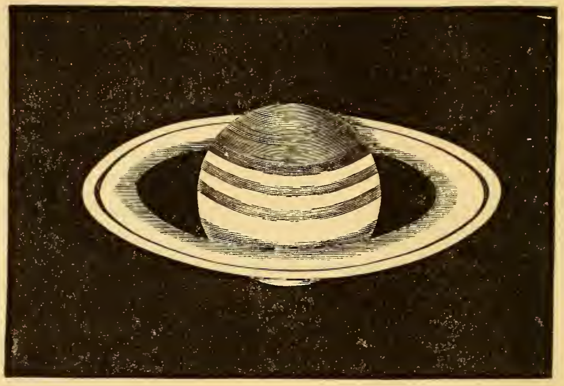
Q. How long is Saturn's YEAR? that is, how long is he in performing his JOURNEY round the SUN?

A. Saturn's year is equal to *twenty-nine and a half* of our years.

Q. What APPEARANCE does Saturn present when viewed through a telescope?

A. It is encompassed by a *broad ring*, and its disc is diversified by *belts* similar to those on the planet Jupiter.

Fig. 54.



The belts or stripes of Saturn are variable in their forms. There is a stripe round the equatorial region which is of a gray colour, and more uniform in its appearance than the rest. The belts do not extend as far as the poles, which being more luminous than the other parts of the planet when they have been turned away from the Sun during their long winter of fourteen years, led Sir W. Herschel to suppose that this brilliancy was caused by snow at the poles of the planet.

Q. Does the telescope reveal any moons belonging to Saturn?

A. Yes; it shows Saturn with eight attendant moons.

Q. Is the axis of Saturn INCLINED to the plane of his orbit?

A. It is; the axis of Saturn is *inclined about thirty degrees* to the plane of its orbit.

Q. What is the CONSEQUENCE of this inclination of his axis?

A. A *change of seasons.*

Q. Are his seasons SIMILAR to ours?

A. They are somewhat similar, only of *greater duration.*

Q. What is the DURATION of each of his four seasons?

A. His spring, summer, autumn, and winter must each continue for the space of *rather more than seven years.*

Q. Are his polar regions, like those of the Earth, alternately DEPRIVED of the LIGHT of the SUN?

A. They are.

Q. How long are they in darkness?

A. They have alternately *fourteen years and three-quarters* of sunlight, and *fourteen years and three-quarters* of darkness.

SECTION V.

Uranus. ♅

"God of the rolling orbs above!
Thy name is written clearly bright
In the warm day's unvarying blaze,
Or evening's golden shower of light;
For every fire that fronts the Sun,
And every spark that walks alone
Around the utmost verge of heaven,
Was kindled at thy burning throne."—PEABODY.

Q. What is the NEXT PLANET beyond the orbit of Saturn?

A. It is called *Uranus*, and sometimes *Herschel*, in honor of its discoverer.

Q. How FAR is Uranus from the Sun?

A. Uranus is about *one thousand eight hundred millions of miles* from the Sun.

Q. What is the SIZE of Uranus?

A. Its diameter is *thirty-five thousand miles.*

Q. What is the LENGTH of a YEAR on the planet Uranus?

A. It revolves in its orbit round the Sun in about *eighty-four* of our years; consequently, his year is equal to eighty-four of ours.

Q. Who DISCOVERED the planet Uranus?

A. It was discovered by *Sir William Herschel* in the year 1781, and it is still known by the name of its discoverer.

Q. Has Uranus any ATTENDANT MOONS?

A. *Six satellites* have been discovered revolving about Uranus, but as they are so remote, they cannot be distinctly seen.

Q. Does Uranus REVOLVE upon its axis?

A. It is supposed to revolve on its axis once in about *nine hours and a half.*

Very little is known concerning this remote planet. The time of its revolution on its axis is not yet *fully* established, nor the inclination of the axis to the plane of its orbit; therefore nothing has been ascertained with regard to its seasons.

SECTION VI.

Neptune. ♆

Q. Is Uranus the MOST REMOTE of all the known planets?

A. It was deemed so till the year 1846, when a *new planet* was detected *beyond* the orbit of Uranus.

Q. What name has been assigned to this yet more distant planet?

A. It is called *Neptune*, or sometimes *Le Verrier*, in honour of its discoverer.

"A brighter day, a bluer ether, spreads
Its lucid depths above our favoured heads;
And purged from mists that veiled our earthly skies,
Shine worlds and stars unseen by mortal eyes."—VIRGIL.

Q. How FAR is Neptune from the Sun?

A. Neptune is *two thousand eight hundred millions of miles* from the Sun, or about *thirty times farther* from that luminary than our Earth.

Q. How LONG is Neptune in performing his journey round the Sun?

A. Neptune performs one revolution in his orbit round the Sun once in *one hundred and sixty-four years.*

Q. How LONG, then, is Neptune's year?

A. His year is equal to *one hundred and sixty-four of our years.*

Q. What is the SIZE of the planet Neptune?

A. It is *forty-one thousand five hundred miles* in diameter.

Q. Who FIRST SAW the planet Neptune?

A. It was first *recognised* as a *planet* by *Dr. Galle* of Berlin; and though it had been frequently *seen* before, it was always supposed to be a fixed star.

It was observed by astronomers that there were certain inequalities in the movements of Uranus, which could be accounted for on no other principle than that of another planet far beyond it. After carefully noting these irregularities, M. Le Verrier *demonstrated* that there must be a planet revolving beyond the orbit of Uranus, and even *designated* in what part of the heavens it might be found; which calculation proved correct. (*See Note* 16.)

Q. Is there any VARIETY OF SEASONS on the planet Neptune?

A. It is not known whether his axis is *inclined* to the plane of his orbit; therefore nothing can be ascertained with regard to his seasons.

Q. How LONG does Neptune require to perform one rotation on his axis?

A. Owing to the immense distance of Neptune, his period of rotation is *unknown* to us; consequently, we have no idea of the length of his day.

Q. Has Neptune any MOONS?

A. *One moon* has been discovered revolving round the planet, and more powerful telescopes may reveal others.

This moon was discovered by Mr. Lassell in 1846. He believes that he also detected a second and smaller satellite in 1850.

Q. Are there any points of GENERAL RESEMBLANCE in the planets Jupiter, Saturn, Uranus, and Neptune?

A. Yes; they are much *larger* than the other planets of our system. The three former are known to be composed

of matter much *less dense*, and to rotate on their axes with much *greater rapidity*, than the planets Mars, Earth, Venus, or Mercury.

Jupiter is eleven times, Saturn ten times, Uranus five times, and Neptune nearly six times, the diameter of our earth.

These four bodies revolve in space at such distances from the Sun, that if it were possible to start thence for each, in succession, and to travel at the uniform railway speed of thirty-three miles per hour, the traveller would reach

Jupiter	in	1712	years.
Saturn	"	3113	"
Uranus	"	6226	"
Neptune	"	9685	"

If, therefore, a person had commenced his journey at the period of the Christian era, he would now have to travel nearly thirteen hundred years before he would arrive at the planet Saturn, more than four thousand three hundred years before he would reach Uranus, and no less than *seven thousand eight hundred* years before he could reach the orbit of Neptune! And yet the light which comes to us from those remote confines of the solar system, first issued from the Sun, and is then reflected from the surface of the planet. When the telescope is turned towards that shining point which the astronomer has dignified by the name of Neptune, the observer's eye sees the object by means of light that issued from the Sun eight hours before, and which since then has passed nearly twice through that vast space which railway speed would require almost a century of centuries to accomplish!!

CHAPTER VI.

The Satellites.

Q. What are SATELLITES?

A. They are *moons*, which serve to enlighten other planets called their primaries, as our Moon enlightens the Earth.

Our Moon is a satellite, of which our Earth is a primary.

Q. Are the moons or satellites known by any OTHER NAME?

A. They are also called *secondary planets.*

Q. Do the satellites revolve round their primaries as a CENTRE?

A. They do.

Q. What is the FORM of the orbits of the satellites?

A. They are usually *elliptical*, though the orbits of the satellites of Uranus are supposed to be very nearly circular.

Q. Have they any OTHER MOTION besides their revolution round their primaries?

A. Yes. They accompany their primaries in their journey *round the Sun*, and have also a motion of *rotation* on their *axes.*

Q. How MANY satellites belong to the solar system?

A. The number of satellites which have yet been discovered is *eighteen.*

Earth has................one.
Jupiter...................four.
Saturn....................eight.
Uranus...................four.
Neptune.................one.

Q. Are the satellites VISIBLE to the NAKED EYE?

A. None of the satellites, *except our Moon,* can be seen without the aid of a telescope.

Q. Are the satellites subject to the same LAWS OF GRAVITATION which govern the primary planets?

A. The satellites are subject to the *same laws of gravitation* as the primary planets.

Q. From WHENCE do they derive their light and heat?

A. From the Sun.

Q. Are the satellites AS LARGE as their primaries?

A. No. The satellites are always smaller than their primaries. The Moon is smaller than the Earth, which is its primary.

SECTION I.

The Moon.

Q. What is the MOON?

A. The Moon is a *satellite,* of which our Earth is the primary.

Q. Has the Earth MORE than ONE satellite?

A. No; our earth has but *one satellite* or attendant moon.

Q. Is the Moon composed of SOLID SUBSTANCE?

A. Yes; the Moon is a *solid globe of matter,* receiving and reflecting the light of the Sun.

"As when the Moon, refulgent lamp of night,
O'er heaven's clear azure spreads her sacred light,
When not a breath disturbs the deep serene,
And not a cloud o'ercasts the solemn scene;
Around her throne the vivid planets roll,
And stars unnumbered gild the glowing pole;
O'er the dark trees a yellower verdure shed,
And tip with silver every mountain's head;
Then shine the vales, the rocks in prospect rise—
A flood of glory bursts from all the skies."

Q. How is it known that the Moon is composed of SOLID MATTER?

A. If we examine the Moon, even without the aid of a telescope, *spots of light and shade* will be seen upon its disc, evidently proving the existence of permanent varieties of surface.

Q. Do these delineations of light and shade APPEAR through the TELESCOPE?

A. Yes; the telescope shows *certain fixed inequalities* in the Moon's surface, such as only belong to a body composed of *solid materials.*

The surface of a fluid body must either assume the appearance of a smooth, unbroken plain, or else it must be constantly changing its aspect with a wavelike motion; but the Moon has certain fixed spots on its surface, which are a proof that it is not composed of fluid matter.

Q. Does the dense matter of which the Moon is composed INFLUENCE the Earth?

A. The force of its *attraction* extends to the Earth.

Q. In what WAY is its attraction shown on the Earth?

A. The *tides rise* chiefly in obedience to the attraction of the Moon's substance.

Q. What indicates the FORCE of the Moon's attraction?

A. The *height* to which the tides are raised show the power of the Moon's attraction, or, in other words, its density.

Q. Does the Moon shine by REFLECTED SUNLIGHT?

A. It does; for if, like the Sun, she were a self-luminous body, she would, like him, always shine with a *full orb;* but when only a portion of the Moon's enlightened hemisphere is visible to us, the remainder is *invisible*, because it is not enlightened by the Sun's rays.

Q. At the time of new moon only a SMALL CRESCENT of its illuminated hemisphere is visible, yet the OUTLINE of the full orb can be distinguished: explain this.

A. The *crescent* is illuminated by the *Sun;* but the remaining part of the Moon's disc is enlightened by the *sunlight reflected from our Earth.*

Q. What is this REFLECTED SUNLIGHT to the inhabitants of the Moon?

A. It is earth-light, or their moonlight; for our Earth gives light to the Moon, as the Moon does to us.

Q. What is the DISTANCE of the Moon from the Earth?

A. The Moon is about *two hundred and forty thousand miles* from the Earth.

Q. How can the Moon's EXACT DISTANCE be ascertained?

A. By observing the *different positions* it seems to occupy in the heavens, when viewed by two observers placed widely asunder on the Earth's surface.

Q. What is the SIZE of the Moon?

A. The Moon is about *two thousand one hundred and sixty miles* in diameter.

Q. How LARGE would the EARTH appear if viewed from the Moon?

A. The Earth would appear *thirteen times* larger than our Moon does to us. (*See Note* 17.)

Q. What is the difference between the BULK of the Moon and that of the Earth?

A. The bulk of the Earth is nearly *fifty times greater* than that of the Moon.

To find the bulk or solid contents of a sphere, multiply the cube of its diameter by the decimal ·5236. Thus, the solid contents of the globe of the Earth is 264,082,024,729 miles, supposing its diameter to be 7960 miles. The solid contents of the Moon, supposing her diameter to be 2160 miles, equals 5,276,681,625 miles; whence it follows, that the *bulk*, or solid contents of the Earth, is nearly fifty times greater than that of the Moon.

Q. Is the Moon's substance as DENSE as the Earth's substance?

A. No; the Moon's substance is rather more than *one-half* less dense than the Earth's substance.

Q. Of what DENSITY is the Earth?

A. The Earth is as dense or heavy as it would be if composed entirely of *metallic iron ore*, a substance which is more than *five times heavier* than *water.*

Q. Of what DENSITY is the Moon?

A. The Moon's sphere is as heavy as it would be if composed entirely of diamond; a substance which is more than three times heavier than water.

Q. Platinum is twice as heavy as silver: if two bullets were made of equal size, one of platinum and the other of silver, how much GREATER would be the mass of the platinum bullet than of the silver one?

A. The mass of the platinum bullet would be equal to *two silver bullets;* that is, its mass would be *twice as great* as the silver bullet, notwithstanding the equality of their bulks.

Q. The Moon has but a FIFTIETH part of the bulk of the Earth, and its substance is much lighter; how much, then, is the Moon's mass LESS than the Earth's mass?

A. The lunar sphere has, in itself, only an *eightieth* part of the Earth's mass.

Q. How can the DENSITY and ABSOLUTE MASS of the Moon's substance be ascertained?

A. By observing the *power* the Moon exercises in attracting other bodies.

Q. In what PROPORTION is the attractive power of a body?

A. The attractive power of a body is always in proportion to its size and density.

Q. What is the FORM of the Moon?

A. It is *spherical.*

Q. How is it KNOWN that the Moon is spherical?

A. That part which is visible always presents the *same appearance* to us which we know a *sphere* would do, if suspended in the sunlight.

Q. How MANY MOTIONS has the Moon?

A. *Three;* one on her own axis, the second in her orbit round the Earth, and the third as an attendant on the Earth round the Sun.

Q. How LONG is the Moon in making one revolution on her axis?

A. The Moon revolves once on her axis in about *twenty-seven days and a quarter.*

Q. How long is the Sun ABOVE the HORIZON on the Moon?

A. As the Moon revolves on her axis once in about twenty-seven days, her term of *daylight* must be the half of twenty-seven days, or nearly *two weeks*, and her *night* must be of the *same length.*

Q. Does the Moon revolve round the EARTH?

A. Yes; the Moon is a *constant companion* of the Earth round the Sun.

"How calmly gliding through the dark blue sky
The midnight Moon ascends!"—SOUTHEY.

Q. How MANY TIMES does the Moon revolve on its axis while it is accompanying the Earth in a revolution once round the Sun?

A. The Moon revolves *once upon its axis* and moves *once round the Earth* in almost exactly the *same length of time;* therefore the Moon must revolve on its axis about thirteen times in one year.

Q. Can any INEQUALITIES or SPOTS be seen on the face of the Moon?

A. Yes; the Moon's disc may be seen to be variegated by *darker and lighter spots*, even by the unaided eye.

Q. Can the MOTION of the Moon on its AXIS be detected by the movement of the spots on its surface?

A. No; for the *same side* of the Moon is constantly turned toward the Earth.

Q. Do the spots hold the SAME RELATIVE POSITION with regard to the surface of the Moon?

A. They do; and also hold the same relative position *with regard to each other.*

Q. As the Moon revolves on its axis, why are not these spots TURNED AWAY from the Earth?

A. This is the inevitable result of the Moon revolving once round the Earth, and once upon its axis in nearly the *same length of time.*

Place a terrestrial globe, or any other body, upon the centre of a round table, and stand looking at it with your back to the fire; then move round the table, keeping your face constantly towards the globe on the middle of the table, and you will find that when you have been once round the table, you will also have made your body turn once round upon itself; for your back is again towards the fire. If you had pinned one end of a long thread to your back before you started to go round the table, and had tied its other end to the poker in the chimney corner, you would find that you had wound the thread once round your person when you had completed your revolution round the table. In the same manner does the Moon revolve round the Earth, keeping the same side always turned towards us. Thus, it must revolve once upon its axis when it has completed one sidereal revolution round the Earth.

Q. Is one side of the Moon's sphere, then, NEVER turned towards the Earth?

A. Yes; there is one lunar hemisphere which is *never visible tc terrestrial eyes.*

Consequently, the inhabitants, if any, of that half the Moon which is invisible to us, can never see the Earth, unless they travel round to the hemisphere which is turned towards us.

Q. Do the times which the Moon requires to revolve upon its axis, and to revolve round the Earth, correspond EXACTLY?

A. No; they do not correspond *precisely*, though very *nearly.*

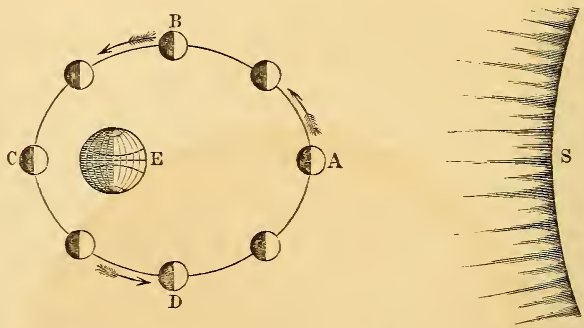
Q. What is the EFFECT of this slight variation in the times of the Moon's revolution round the Earth and round its own axis?

A. The inhabitants of the Earth are enabled to see, sometimes a little farther round *one side* of the Moon, and sometimes a little farther round the *other side.*

Q. What is the VIBRATION, or showing a little on one side, and then a little on the other side, CALLED?

A. It is called the Moon's *libration in longitude.*

Fig. 55.



In *fig.* 55, E represents the Earth, and A B C D the Moon in her elliptical orbit round the Earth: from D through A to B the Moon's orbitual motion is slower than her revolution on her axis, by which means we are enabled to see more of her *eastern* limb; but from B through C to D her orbitual motion is faster than her revolution on her axis, which enables us to see more of her *western* limb.

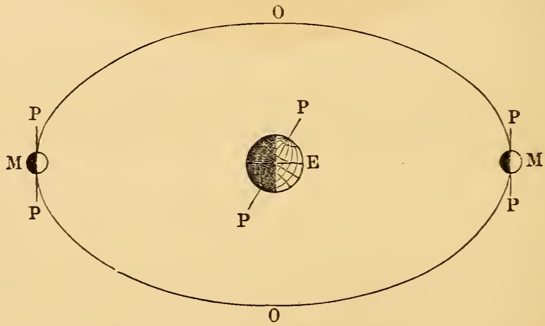
Q. Is there any OTHER VIBRATION perceptible in the Moon?

A. Yes; sometimes a little more of the *north pole,* and then a little more of the *south pole* is brought into view.

Q. What is the showing sometimes a little more of one pole, and then a little more of the other pole, CALLED?

A. It is called the Moon's *libration in latitude.*

Fig. 56.



Suppose in the figure, E to be the Earth, and M M the Moon moving in O O. its elliptical orbit; the Moon's axis of rotation is placed perpendicularly to the plane of its orbitual

movement, as the lines P P in the figure are perpendicular to the curved line O O. Now, the reason that sometimes one pole, and sometimes the other, is more brought into view, is, that the Moon's axis is so very little inclined to the plane of its orbit. This vibration is called the Moon's libration in latitude.

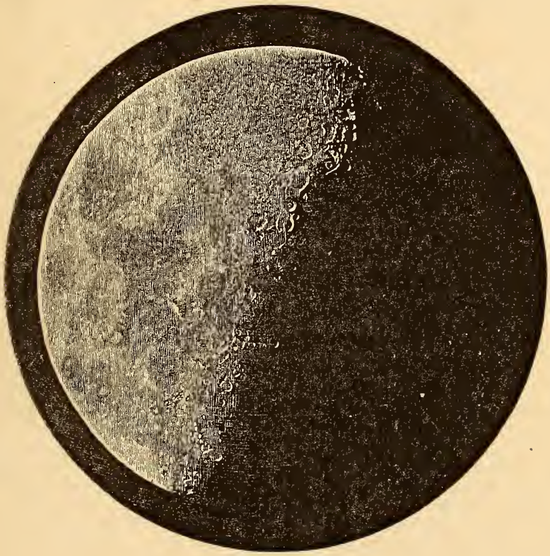
Q. Is the Moon's axis INCLINED with regard to the direction in which it moves round the Earth?

A. Yes; though the Moon's axis is *very nearly* perpendicular to the plane of its orbit round the Earth, it has the small inclination of 1° 30′ 10″.

Q. Does the Moon always present itself to the inhabitants of the Earth under the form of an ENLIGHTENED HEMISPHERE?

A. No; sometimes only a *portion* of its enlightened hemisphere is visible to us, as in the following figure.

Fig. 57.



This figure represents a telescopic view of the Moon, taken by the daguerreotype process, at the Cambridge Observatory, Massachusetts.

Q. When is ALL of the enlightened half of the Moon visible to us?

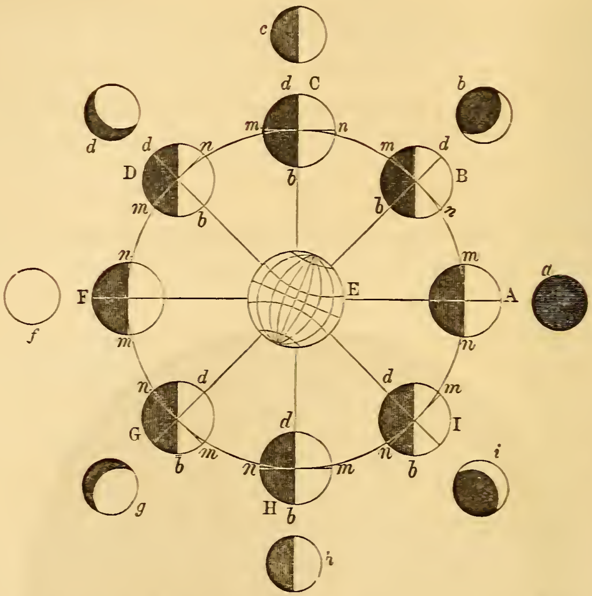
A. At the period of *full moon.*

———"Till the Moon,
Rising in clouded majesty, at length,
Apparent queen, unveiled her peerless light,
And o'er the night her silver mantle threw."—MILTON.

Q. Why is ALL the enlightened half of the Moon's sphere visible at the time of full moon?

A. Because the Earth's inhabitants see the Moon's sphere in the *same direction* from whence the Sun's rays pass to illuminate it.

Fig. 58.



In the above figure let E represent the Earth, and A B C D, &c. the Moon in different parts of her orbit. It is plain that when the Moon is at A, in that part of her orbit between the Earth and the Sun, her enlightened hemisphere is turned away from us, consequently she is invisible. As she advances in her orbit from A to C, she first appears a slender crescent, which increases in size till at C one-half the disc towards us is enlightened; at this period she is said to be in her *first quarter*. From C to F she shows still more and more of her enlightened hemisphere, till at F, being directly opposite to the Sun, her disc appears perfectly round. She is then *full*. From F, her enlightened half is only partly visible, and on her arrival at H only half of her illuminated hemisphere can be seen. In this position she is said to be in her *last quarter*. From H to A she appears to diminish in size till she becomes a narrow crescent, and at A is finally lost in the Sun's beams,—her dark side being entirely turned towards us.

In the figure, *m n* represents the half of the Moon which is turned towards the Earth, and *b d* a line joining the centres of the Earth and Moon. When the Moon is at A, its dark side is turned towards us as at *a*; at B only part of her illuminated disc can be seen as at *b*; at C she has half her enlightened side towards us, and then appears a half moon as at *c*; at F she is directly opposite the Sun, and presents a full orb as at *f*. At B and I she is a crescent; at D and G she appears gibbous. When at C she is in her *first quarter*, and at H in her *last quarter*.

When at A the Moon is in *conjunction*; that is, she appears in the same quarter of the heavens with the Sun; and when at F she is in *opposition*; that is, in that part of the heavens *opposite* to the Sun. The two positions of the conjunction and opposition are called *syzigies*, and those of the first and last quarters *quadratures*. The position at B is called the first octant, D the second octant, G the third octant, and I the fourth octant.

Q. When can NO PART of the enlightened half of the Moon's sphere be seen?

A. At the period of *new moon*, or when at A, (*fig*. 58.)

Q. Why can NO PORTION of the enlightened half of the Moon be seen at the period of new moon?

A. Because to the Earth's inhabitants the Moon's sphere is in

the *same direction* as the Sun, the dark half being turned towards us, and the Sun's light falls upon the other, for which reason it is invisible to us, as at A, (*fig.* 58.)

If a candle be placed upon a table before an observer, and a small round ball be held between its flame and the eye, the eye only rests upon the half of the ball which is not illuminated by the candle, and the half enlightened by the direct rays of the candle is invisible, because turned from us.

Q. What APPEARANCE does the Moon assume when its enlightened half is neither altogether visible nor entirely concealed?

A. It assumes the various forms from a narrow crescent to *almost* a full circle, being a little flattened on one side.

"The Queen of Night
Shines fair with all her virgin stars about her."—OTWAY.

Q. The Moon's hemisphere sometimes presents the appearance of ALMOST a full round disc: what is this form CALLED?

A. The Moon is then said to be *gibbous.*

Q. By what NAME are the varying appearances of the Moon known?

A. They are called the *phases* of the Moon.

Q. How are the VARYING APPEARANCES of the lunar phases produced?

A. By the gradual and successive *appearance* and *disappearance* of the enlightened hemisphere of the Moon.

"By thy command the Moon, as daylight fades,
Lifts her broad circle in the deepening shades;
Arrayed in glory, and enthroned in light,
She breaks the solemn terrors of the night;
Sweetly inconstant in her varying flame,
She changes still, another, yet the same!
Now in decrease, by slow degrees she shrouds
Her fading lustre in a vail of clouds;
Now of increase, her gathering beams display
A blaze of light, and give a paler day.
Ten thousand stars adorn her glittering train,
Fall when she falls, and rise with her again;
And o'er the deserts of the sky unfold
Their burning spangles of sidereal gold;
Through the wide heavens she moves serenely bright,
Queen of the gay attendants of the night;
Orb above orb in sweet confusion lies,
And with a bright disorder paints the skies."—BROOME.

Q. How is it that DIFFERENT PROPORTIONS of the enlightened half of the Moon are visible to the inhabitants of the Earth at different times?

A. Because the Moon is constantly *changing her position* with regard to the Earth and Sun.

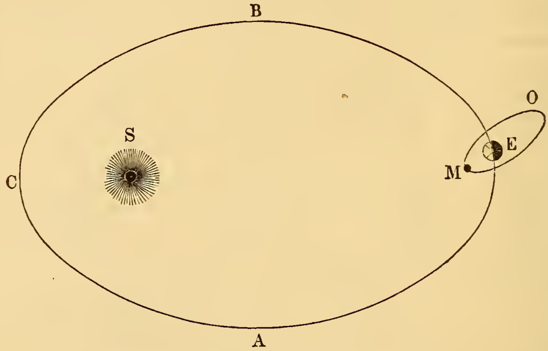
Q. What is the MOTION of the Moon with regard to the Earth and Sun?

A. It moves *round the Earth* in an elliptical orbit, and also *accompanies* the Earth in her yearly revolution round the Sun.

Q. In what PART of the Moon's elliptical orbit is the Earth placed?

A. The Earth is placed in *one of the foci* of the ellipse, just as the Sun occupies one of the foci of the Earth's elliptical orbit.

Fig. 59.



In *fig.* 59, A B C represents the orbit of the Earth, and M O that of the Moon. The Moon M revolves round the Earth E, and also accompanies the Earth in her orbit round the Sun S.

Q. With what VELOCITY does the Moon move in her orbit?

A. She moves in her orbit round the Earth at the rate of about *two thousand three hundred miles* per hour.

Q. What is the apparent ANGULAR MOTION of the Moon in a day?

A. The Moon appears to move through rather more than *thirteen degrees* of the circumference of the heavens in one day.

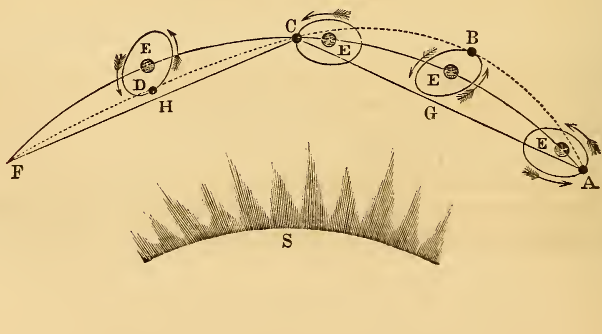
Q. If, then, the Sun be in conjunction with the Moon on any given day, how MANY DEGREES of angular measurement will she be from him on the following day?

A. The Sun only appears to move about one degree per day, while the Moon moves more than thirteen; therefore they will be more than *twelve degrees* asunder on the following day.

Q. The Moon's orbit is an ellipse; but is it a REGULAR CURVE?

A. No; the Moon's orbit is an *irregular curve,* always *concave towards the Sun.*

Fig. 60.



The plain line A E C E F represents the orbit of the Earth, and the dotted one that of the Moon. At A the Moon crosses a point of the Earth's orbit which the Earth has already passed. At the expiration of about one-fourth of a lunation she arrives at B, at which time the Earth is between the Moon and the Sun,—consequently it is *full* moon; pursuing her course, she is now in advance of the Earth, and crosses her orbit at C; from C she continues her course, till at D she is between the Earth and the Sun,—consequently it is *new* moon; from D she approaches nearer and nearer to the orbit of the Earth, till at F she again crosses it, 240,000 miles behind the Earth. This completes one lunation or revolution of the Moon round the Earth.

That the orbit of the Moon is concave towards the Sun, may be explained thus: Let A G C be a chord of the arc A B C, a part of the Moon's orbit, and C H F a chord of the arc C D F, another portion of the Moon's orbit: it will be seen that the dotted line representing the Moon's orbit is always concave towards the Sun. Thus, A G C is a chord of the arc A E C, which is a part of the Earth's orbit, and the dotted line A B C, representing a portion of the Moon's orbit, is evidently concave towards the sun S; so C H F is a chord of the arc C D F, another portion of the Moon's orbit, and this chord being a straight line, it follows that the arc C D F must be concave towards the Sun S. Now, as this figure represents one lunation, it will be seen that the Moon has *really* made one complete revolution round the Earth as she moved in her orbit from A to F.

Q. How is the Moon UPHELD in her place in space?

A. By the combined influence of the *centrifugal* and *centripetal forces;* that is, the *projectile force* of the Moon, and the *attraction* of the Earth; or in other words, by the influence of *motion and attraction.*

Q. How LONG does it take the Moon to COMPLETE one of her elliptical journeys round the Earth; that is, from one star to the same star again?

A. *Twenty-seven days* and three tenths of another day.

Q. What is that PERIOD CALLED in which the Moon completes a revolution around the Earth; that is, from one star to the same star again?

A. It is called a *sidereal revolution,* or period of the Moon.

Q. How is it known when the Moon has COMPLETED one of its elliptical journeys round the Earth?

A. It is observed that the Moon has *returned* to the same *relative position* with regard to the stars.

Q. When the Moon is seen in conjunction with a star, does it seem to TOUCH the same star again when it has completed one revolution?

A. No; when it has completed its revolution, it is either *above* or *below* the place it last occupied when in that part of the heavens.

Q. How is it known that the Moon does not move round the Earth in a PERFECTLY CIRCULAR path?

A. The Moon sometimes *measures more* than at other times, and therefore must be *nearer* to the Earth sometimes than at others.

The Moon's disc sometimes measures 4 minutes 10 seconds more than at others. She seems, also, to move faster with regard to the fixed stars than at other times. Her motion is greatest when nearest to the Earth; for then her momentum is increased, to resist the power of the Earth's attraction.

Q. Does the Moon complete a SUCCESSION of her PHASES in the SAME TIME in which she completes one revolution about the Earth?

A. No; a succession of phases occupies more than *two days longer* than one revolution about the Earth.

Q. What is the EXACT TIME which the Moon requires to complete a succession of phases?

A. About *twenty-nine days and a half.*

Q. What is this PERIOD CALLED in which the Moon completes one series of phases?

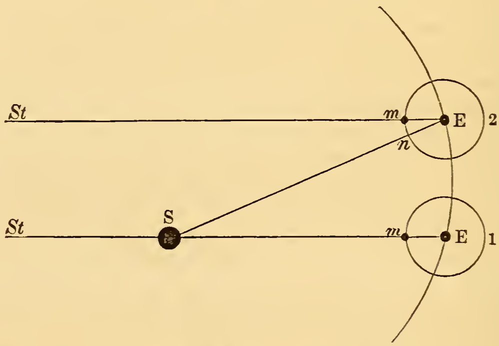
A. A *synodic* revolution of the Moon, or *lunar month.*

"Then marked Astronomers with keener eyes
The Moon's refulgent journey through the skies."—DARWIN.

Q. Why does the Moon require longer to complete a succession of its PHASES, than to complete a revolution round the Earth?

A. Because when the Moon has gone once round the Earth, the Earth has advanced in her orbit in the same general direction. Thus, the Moon must move on a certain time longer before it is again between the Earth and the Sun, to mark the commencement of a new lunation.

Fig. 61.



Let S represent the Sun, and *m* the Moon between the Earth E 1 and the Sun. Let *St St* represent a particular star. Now, when the Moon has moved once round the Earth, which is known by its coming once more between that particular star *St* and the Earth, the Earth will have advanced in its orbit from the position 1 to the position 2; but the Moon will not then be again between the Sun and the Earth. It must move on to *n* before it is so, and the additional time it requires to come again between the Sun and the Earth is the difference between the periods in which one succession of the lunar phases and one lunar revolution round the Earth are completed.*

Q. Is the Moon's axis INCLINED to its own orbit?

A. The Moon's axis is very nearly upright or perpendicular to the plane of its orbit, being inclined to it only 1° 32′ 9″.

Q. How much is the Moon's orbit INCLINED to the plane of the ecliptic? or, in other words, what ANGLE does the Moon's orbit make with the orbit of the Earth?

A. The Moon's orbit is inclined, or makes an angle of about *five degrees* with the orbit of the Earth.

---

* The two parallel lines *St St* are drawn to represent the direction of *one* and *the same star*, because the stars are so immensely distant from us, that the lines leading to them from the Earth in different parts of its orbit can never be found to have any convergence towards each other; they are so nearly parallel, that practically they are quite so.

Q. The path or orbit of the Moon crosses the Earth's orbit in TWO POINTS: what are those two points called?

A. They are called the Moon's *nodes.*

Let the edge of a circular table represent the orbit of the Earth round the Sun; the *surface* of the table would be the *plane* of the orbit. Now, the Moon revolves round the Earth in an orbit inclined 5° to the Earth's orbit; so that one-half of the Moon's orbit would lie 5° below the surface of the table, and the other half 5° above it. The points of intersection with the edge of the table would represent the Moon's nodes.

Q. Has the Moon the same VARIETY of SEASONS with the Earth?

A. She has *not.* As her axis is nearly perpendicular to the plane of her orbit, she cannot have any material change of seasons.

The half of the Moon towards us has the advantage of reflected light from the Earth; for in the absence of the Sun it is illuminated by our Earth, which would appear thirteen times larger than the Moon does to us. The inhabitants have two weeks of sunshine, and two weeks of moonlight. But the inhabitants on the other side of the Moon never see our Earth; consequently, they have no moonlight, but two weeks of sunlight and two weeks of darkness.

Q. What would be the appearance of the NOCTURNAL SKY to the inhabitants of that hemisphere of the Moon which is always TURNED AWAY from us?

A. The heavens would have the same appearance that our own sky does on moonless nights, except that as the Moon revolves so slowly on her axis, the stars would be *fourteen of our days* from their rising to their setting.

Q. What would be the appearance of the NOCTURNAL SKY to the inhabitants of that hemisphere of the Moon which is always TURNED TOWARDS us?

A. They would see our Earth, which would be to them a *moon,* presenting a disc thirteen times larger than the Moon's disc, and passing through all the phases from a crescent to a full moon once a month.

Q. Would the Earth seem to them to RISE and SET, as the Moon does to us?

A. No; the Earth would seem almost fixed in the lunar sky.

If a spectator were placed on the surface of the Moon, at the centre of the hemisphere towards us, he would see our Earth revolving on her axis once in twenty-four hours, and presenting all the phases of the Moon once in a month. Our Earth would be variegated by spots corresponding to the clouds, and belted, owing to the trade-winds. At the time of an eclipse of the Sun to them, the atmosphere of our Earth would appear like a halo, or ring of a ruddy color fading into pale blue.

Q. Does the Moon REFLECT on the Earth any portion of the solar HEAT which she receives?

A. It is generally believed that there is *no perceptible heat* in moonlight. (*See Note* 18.)

Q. Why does the Moon MOVE ROUND the Earth?

A. Because the Earth's substance *attracts* the Moon's substance.

Q. Then, why does not the Moon FALL to the Earth?

A. Because as the momentum of the Moon's velocity impels it in a *different direction* to the attractive power of the Earth, it consequently obeys neither, but pursues a path *between the two.*

Q. Does not the Moon's substance ATTRACT the Earth's substance as well as suffer attraction by it?

A. It *does;* but as the Moon's mass is so much less than the Earth's mass, her attractive power is *proportionably less.*

Q. Does the Sun's substance also INFLUENCE the Moon's substance?

A. Yes; the Moon is attracted *by the Sun* as well as by the Earth?

Q. How is the attractive INFLUENCE of the Sun over the Moon made manifest?

A. By certain perceptible *irregularities of movement* which the Moon suffers. (*See Note* 19.)

Q. Has the Moon an ATMOSPHERE?

A. It is supposed to be void of atmosphere of *sufficient density* to be worthy of the name of *air*.

Q. Are there any CLOUDS surrounding the Moon?

A. The moon has *no clouds*, nor any other decisive indications of an atmosphere.

If the Moon has an atmosphere at all like ours, clouds could be perceived floating in it; but no such appearances have ever been detected. Besides, the outlines of all the inequalities on its surface are sharp and well-defined; which would not be the case if there was an atmosphere similar to ours.

Q. How can the ABSENCE of an atmosphere in the Moon be PROVED?

A. Should there be any *appreciable* amount of vapor suspended near the surface of the Moon, the light of very faint stars would be diminished or *extinguished* before occultation, which is not the case

Q. During a TOTAL ECLIPSE of the Moon is there any indication of an ATMOSPHERE?

A. Very minute stars are seen to pass under the edge of the Moon, and undergo *sudden extinction;* whereas, if the Moon had an atmosphere at all like ours, they would disappear gradually. (*See Note* 20.)

M. M. Baer and Mäedler, two noted German astronomers, who have made the most extensive selenographical researches hitherto attempted, have arrived at the conclusion that the Moon is not *entirely without* an atmosphere, but owing to the smallness of her mass she is incapacitated from holding an extensive covering of gas; and they add, "It is possible that this weak envelope may sometimes, through local causes, in some measure dim or condense itself." But if any atmosphere exists on our satellite, it must be, as La Place says, more attenuated than what is termed a *vacuum* in an air-pump.

Q. Does the Moon rise at the SAME HOUR every day?

A. No; she rises about *three-quarters of an hour later* each day than on the one preceding.

Q. Why does she rise LATER and LATER every succeeding day?

A. Because the Moon *advances* in her orbit about *thirteen degrees* per day, on which account any place on the Earth must make more than one complete rotation before it arrives again in the same situation with regard to the Moon?

Q. Does the Moon rise about three-quarters of an hour later every day to ALL PLACES on the Earth?

A. The difference of time of the Moon's rising at the equator is nearly three-quarters of an hour, or, more properly, *fifty minutes;* but in high latitudes the difference is much less in the months of August and September.

Q. Why is there LESS DIFFERENCE in the times of the Moon's rising in the months of August and September than at any other time of the year?

A. Because in the months of August and September the Sun is in the signs Virgo and Libra, which places the *full* moon in the opposite signs of Pisces and Aries; and in high latitudes as much of the ecliptic rises about Pisces and Aries in two hours as the Moon passes through in six days; therefore, when the full moon is in these signs, she differs in the time of her rising but about *twenty minutes a day*, for nearly six days.

Q. Does the full moon in these months render any essential service to HUSBANDMEN?

A. Yes; because in the months of August and September, which are the harvest months to the inhabitants of the higher latitudes, the husbandmen have the light of the full moon for several consecutive nights *immediately after sunset*, which enables them to gather in their grain.

Q. Was the phenomenon of the Moon's rising after sunset for several nights together, known to the ANCIENTS?

A. Yes; it was observed by persons engaged in agriculture at a much *earlier period* than it was noticed by astronomers, and has been long known by the name of the *Harvest Moon.*

"There is a time well known to husbandmen,
In which the Moon for many nights, in aid
Of their autumnal labors, cheers the dusk
With her full lustre, soon as Phœbus hides
Beneath the horizon his propitious ray;
For as the angle of the line which bounds
The Moon's career from the equator, flows
Greater or less, the orb of Cynthia shines
With less or more of difference in rise;
In ARIES least this angle; thence the Moon
Rises with smallest variance of times
When in this sign she dwells; and most protracts
Her sojourning in our enlightened skies."—LOFFT.

During the latter part of the harvest months, or when the Moon is in Aries, it is called the *Hunter's Moon.* At the poles, one-half of the year, the ecliptic never sets, and during the other half it never rises; consequently, the Sun continues one-half the year above the horizon, and the other half below it. The full moon being always opposite to the Sun, can never be seen to the inhabitants of the poles during their summer, but in winter they have the benefit of her light for the space of fourteen days and nights at a time, without intermission. The inhabitants of the poles are not deprived of the light of the Sun for quite six months, because the atmosphere *refracts** the Sun's rays, by which means he becomes visible about two weeks earlier, and continues to be seen two weeks later, than he otherwise would do. The inhabitants of the polar regions have a tolerable share of light afforded them by the meteoric phenomenon called the *Aurora Borealis.*

"By dancing meteors, then, that ceaseless shake
A waving blaze refracted o'er the heavens,
And vivid moon's and stars that keener play

* See Part iii. chap. i. sec. i. div. iii.

With double lustre from the glossy waste;
Ev'n in the depth of polar night, they find
A wondrous day; enough to light the chase,
Or guide their daring steps to Finland fairs."—THOMSON.

Q. Why does the Moon's disc appear MOTTLED?

A. Because some parts *reflect* the Sun's rays, and other portions are in *shadow.*

Q. How can these various appearances in the Moon's disc be ACCOUNTED for?

A. The brighter portions are *elevations*, which receive the Sun's rays, while the darker portions are *cavities*, or comparatively *level tracts*, which reflect less sunlight.

Q. Can these elevations and cavities be discerned by the NAKED EYE?

A. No; but by means of the *telescope* we can aid the eye in making the investigation.

By the unaided eye we can observe the lights and shadows on the Moon, but we cannot discern them to be inequalities on its surface.

Q. How can the TELESCOPE aid our sight?

A. It makes any celestial body appear *much nearer* to the observer than it really is.

Q. How can it make the Moon appear NEARER to us?

A. The object-glass of the telescope *collects more rays* from any visible object than the eye can, and the eye-glasses of the telescope, by magnifying the object, spread its image over a larger *sensitive surface* within the eye, and therefore allow the details to be seen more *accurately and distinctly.*

Q. How NEAR can the Moon be made to appear by the aid of a telescope?

A. The Moon being so much nearer to us than any other heavenly body, the telescopic power is more conspicuous when directed to it. The surface of the Moon can be as distinctly seen by a good telescope magnifying 1000 times, as it would be if not more than *two hundred and fifty miles distant.*

Q. What DISCOVERIES have been made, by means of the telescope, on the surface of the Moon?

A. *Elevations* of great dimensions have been discovered on the Moon, which cast distinct *shadows* when the Sun shines obliquely on them. Deep *cavities*, also, are to be seen, unlike any thing of the kind on our globe.

Q. When do terrestrial objects cast the LONGEST shadows?

A. At the time of sunrise or sunset; that is, when the Sun's rays fall the most obliquely upon them.

For this reason, when the Sun shines obliquely, or when he is rising or setting to that side of the Moon towards us, the shadows cast by the lunar elevations are the longest and most plainly seen by the aid of the telescope.

Q. To what PART of the visible half of the Moon is the Sun RISING OR SETTING at any given time?

A. It is rising or setting on the line which separates the *illuminated* from the dark part of the Moon's disc.

Fig. 62.

Suppose, in the above figure, M to be the Moon with its enlightened half turned towards the Sun S; then it would be sunrise or sunset along the border of the light half where it joins to the dark, indicated in the figure by the line of dots; for that is the part of the spherical surface just emerging into the Sun's rays or receding from them; while along that part marked *a a a* it would be midday.

Q. When the Sun shines VERTICALLY over any part of the Earth, are there any shadows cast?

A. No; there are *no shadows* cast at those places under a vertical sun.

Fig. 63.

Fig. 63 is a telescopic representation of the full Moon taken at the Cambridge (Massachusetts) Observatory, by the daguerreotype process.

"Lo! the beauteous Moon
Like a fair shepherdess, now comes abroad
With the full flock of stars, that roam around
The azure meads of heaven."—ROBERT MONTGOMERY.

Q. Why cannot long shadows be seen at the time of FULL MOON where the solar rays FALL OBLIQUELY?

A. Because the shadows are then cast *behind* the projecting objects *as regards the position of the observer*, as well as regards the position of the Sun.

6

Q. At the time of FULL MOON, in what POSITION is the observer with regard to the Sun and Moon?

A. The Earth is then *between* the Sun and Moon; consequently, we look upon the Moon in the *same direction* from whence the rays of the Sun proceed.

Q. When can the shadows cast behind projections from the lunar surface be seen MOST ADVANTAGEOUSLY?

A. At the *first* and *last quarters* of the lunation; or in other words, at the time of *new moon* and *old moon.*

Q. Why are the shadows MOST PERCEPTIBLE at the first and last quarters of the lunation?

A. Because the observer can then see the *full length of the shadows* cast behind the eminences.

Fig. 64. (LUNAR SHADOWS.)

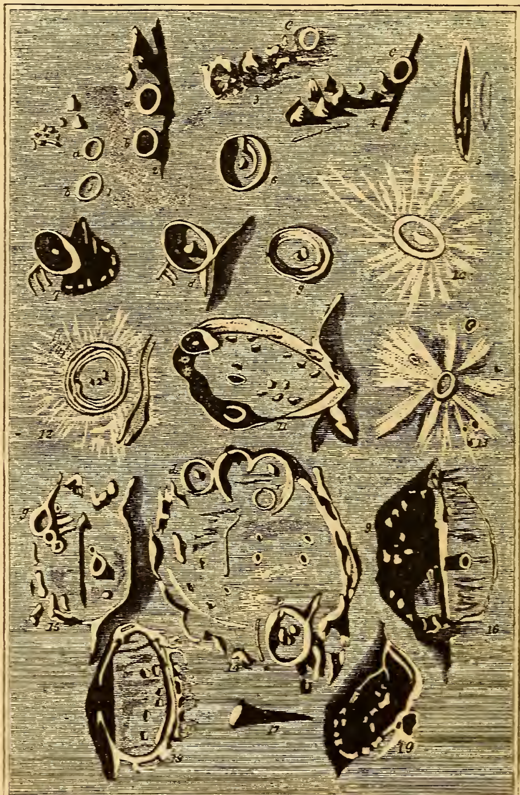


Fig. 17 (Lunar Shadows) represents the appearance of a shadow cast behind a pyramidal elevation on the Moon's surface on the eighth day after new moon. This peak is near the upper part of the Moon's disc, and is denominated Pico.

Q. Why are the LUNAR SHADOWS objects of GREAT INTEREST for terrestrial observers?

A. Because they enable them to ascertain the *height* of the elevations of the Moon's surface, and because they render the forms and outlines of those elevations *more distinct* than they would otherwise be.

Q. How can the HEIGHT of a lunar mountain be ascertained by observing its shadow?

A. The length of a shadow is always *proportioned to the height* of the body casting it.

Q. Does the INCLINATION at which the light falls on a body aid in determining its height?

A. It does. Whenever light falls on a body at an inclination of *half a right angle*, that is, 45° above the horizon, a shadow is cast *exactly as long as the body is high.*

Q. When the light falls with a LESS INCLINATION than 45° above the horizon, is the shadow longer or shorter than the object?

A. When the light falls with a *less* inclination than 45° above the horizon, the shadow is proportionately *lengthened;* when it falls with a greater inclination, the shadow is proportionately shortened, until it arrives at the zenith, when there is no shadow at all.

Q. To what EXTENT do the lunar elevations rise above the general surface of the sphere?

A. Some of them rise to the height of *twenty-four thousand feet;* an elevation nearly as great as that of the highest peaks of the Andes on our globe.

Q. Are the mountains on the Moon HIGHER in proportion than those on our Earth?

A. The mountains on the Moon are on a *much grander scale* than those on our Earth. If Chimborazo were as high in proportion to the Earth's diameter as a mountain in the moon known by the name of Newton is to the Moon's diameter, its peak would be more than 16 miles high.

Q. How do the lunar shadows increase the DISTINCTNESS of the forms of elevation on the Moon's surface?

A. They make otherwise inconspicuous elevations *more distinct* by means of the dark shadow which borders them.

Fig. 3 (Lunar Shadows) shows the appearance of the commencement of a chain of lunar peaks, known by the name of the *Apennines,* on the tenth day of the lunation. *Fig.* 4 of the figure is a sketch of the same chain on the eighth day, when long shadows are cast behind them. On account of the distinctness with which objects seem to stand out when bordered by their dark shadows, they appear to be many times larger when accompanied by their shadows than they do when without them.

Q. Do the lunar elevations wear the SAME GENERAL FORM as the terrestrial mountains?

A. With *few exceptions,* the form of the lunar mountains differs from those on our Earth.

Q. What, then, is the USUAL appearance of the lunar mountains?

A. In the vast majority of instances they have the form of

circular ridges surrounding *cavities*, and these cavities have frequently *isolated peaks* rising from their centres.

Fig. 6 (Lunar Shadows) shows the appearance of one of these circular ridges, which may be selected as a type of the whole. The sketch is taken from an object which the selenographists have called Manilius, and represents it as it may be seen on the eighth day of the lunation. It will be observed that a deep, black shadow is cast *within* the left-hand side of the circle, and *without* its right-hand side; and that an isolated peak arises from the centre of the cavity, casting a conical shadow in the same general direction. The length of the shadow *inside* the cavity, compared with that on the outside, indicates that the central cavity is far below the general surface of the Moon; that, in other words, the circular ridge encloses a cavity, hollowed out into the lunar substance. This circular ridge, called Manilius, rises 7600 feet above the general surface of the Moon.

Q. Are there MANY of these circular depressions on the Moon's surface?

A. In many parts the Moon's surface is *completely studded* with them. No less than 148 large cavities of this description have been measured, besides which there are numerous small ones.

Q. What is the BREADTH of these lunar cavities?

A. Most of them are from *one* to *ten* miles in diameter; but some are much larger.

Manilius, sketched in *fig.* 6, (Lunar Shadows,) is about 25 miles wide. *Fig.* 11 gives the appearance of a large cavity, called Clavius, on the tenth day of the lunation. This cavity measures 143 miles across. It will be observed that there are several secondary cavities opened out on its floor, and that the floor is surrounded by an irregular ridge, rising in this instance to the height of 18,000 feet. This height is indicated by the long shadow cast within the border of the cavity. *Fig.* 5 shows the foreshortened elliptical form of a cavity, called Humboldt, situated near the right edge of the Moon, as it is seen on the sixteenth day of the lunation. A central peak rises within the ring-shaped ridge; and two small black shadows thrown across the left edge of the cavity show that high peaks tower on the opposite side.

Q. Are the shadows, cast behind the lunar elevations, seen to SHORTEN as the Sun rises upon them?

A. Yes. When the peaks and ridges first come into light, they have *very long* shadows beyond them; but the shadows then *grow shorter and shorter*, until at last they disappear.

Fig. 2 (Lunar Shadows) shows the appearance of the shadows cast behind the terminal peaks of the ridge called the Apennines, and within and behind the cavities called Antolycus and Aristillus, on the seventh day of lunation. *Fig.* 1 gives the appearance of the same object twenty-four hours after. It will be observed that the shadows behind the peaks have been shortened by more than three-fourths; and the shadow inside the circular ridges is so far withdrawn that half the contained plain is uncovered. In Aristillus, the summit of a central peak is seen, just rising beyond the shadow.

In *fig.* 7 (Lunar Shadows) the shadows of the large cavity called Tycho are represented as they may be seen six hours before the completion of the ninth day of the lunation. The chief part of the internal depression then lies in shadow; but a central peak rears its summit through the shadow, high enough to catch the sunbeams. To the right, the circular ridge throws its outer shadow; but a few elevated peaks are already in light beyond. *Fig.* 8 gives the appearance of the same object four hours later; the internal shadow is withdrawn from the greater portion of the floor of the cavity, and the central peak is entirely revealed, with its own shadow cast upon the illuminated portion of the floor of the cavity. *Fig.* 9 represents the appearance of the same (Tycho) on the tenth day of the lunation. All the shadows are here very much diminished; and one or more smaller peaks are visible, standing near the base of the larger central one. This cavity is 55 miles wide; its circular ridge is 17,000 feet high; and the larger central peak cannot have less elevation than one mile.

Q. Do the lunar shadows decrease as QUICKLY as the terrestrial shadows, when the Sun is in the act of rising upon the objects which cast them?

A. No; they require a period *twenty-nine times greater* than

the terrestrial shadows, because the Moon revolves on her axis so slowly as to make the lunar day equal to twenty-nine of our days. Therefore, her shadows decrease proportionably slower than those on the Earth.

In *fig.* 19 (Lunar Shadows) is a cavity named Petavius, as seen on the seventeenth day of the lunation. The serrated tops of the left-hand border of the ridge may be noticed in light, while all the cavity and outer surface on that side are yet in darkness. The central peak terminates in several broken summits, already illuminated.

Q. Are the shadows always seen on the SAME SIDES of the lunar elevations?

A. No. Before the full moon the shadow is cast on the left side of the elevations, that is, towards the east; and after the full moon it falls on the right side, or towards the west.

Fig. 15 (Lunar Shadows) represents the shadows cast behind certain projecting objects, near a cavity bearing the name of Thebit, on the eighth day of the lunation. It will be observed that there is in both sketches a long ridge, crossing the centre of a sort of oval plain. In *fig.* 15 a deep shadow is cast by this declivity. In *fig.* 16 its surface lies in bright sunshine. A small cavity to the right of the ridge casts its shadow *away from* the ridge in *fig.* 15, but *upon it* in *fig.* 16. In the two cases the shadows are reversed. In *fig.* 15 the floor of the large cavity Thebit, marked *g*, is half illuminated; in *fig.* 16 it is in entire darkness, but the highest peaks of its ring-shaped ridge have just caught the sunshine.

Q. Do the Moon's circular ridges bear any resemblance to the VOLCANIC CRATERS on our Earth?

A. They do not; they are much *more vast*, and are characterized by entirely different features.

Q. What is a TERRESTRIAL VOLCANIC CRATER?

A. The *aperture* or *mouth* of a terrestrial volcano.

Q. What do the lunar cavities RESEMBLE?

A. *Circular pits* of large size, excavated in the Moon's surface, and fringed with elevated rugged edges.

Terrestrial volcanic craters are for the most part situated on the summits of *elevated peaks;* while the lunar craters, as they are sometimes called, are mere *depressions*, or *surface cavities.*

Q. Can any opinion be formed of the PROBABLE DIFFERENCE of the forces that have given rise to mountain projections in the Earth and in the Moon?

A. The terrestrial projections seem to have been forced up by powers acting at a *great distance* beneath the surface, and extending over a large space. The annular ridges of the Moon seem to have been formed by forces that have had a very *confined range*, both as regards depth and extent.

Q. Are there no instances on the Moon's surface in which an EXTENSIVE AREA has been disturbed during the production of a crater?

A. There is *one isolated instance* in which such extensive disturbance appears to have taken place.

Q. What is the NAME of this isolated object?

A. It is called *Tycho.* There are *cracks* radiating from it, extending in one direction at least *seventeen hundred miles.* Traces of these cracks are visible about the time of full moon.

Fig. 10 (Lunar Shadows) represents the appearance of these cracks around Tycho the day after full moon. *Fig.* 12 shows the crater Copernicus as it appears on the tenth

day of the lunation, with its basket-worklike concentric ridges, and its three isolated peaks. The other is the crater Kepler, sketched in *fig.* 13, as it may be seen on the twelfth day of the lunation. Copernicus is 55 miles in diameter, and its circular ridge is above 11,000 feet high. The crater of Kepler is 22 miles in diameter, and its sides tower 10,000 feet above the internal floor.

Q. Are there NO OTHER KIND of mountainous elevations upon the Moon's surface besides these circular ones?

A. There are examples both of *extended ridges* and *isolated peaks* without any surrounding ring; but these are of rare occurrence, when compared with the number of the ring-shaped ridges.

Q. What does the telescope show to be the nature of those portions of the lunar surface that are of INFERIOR BRILLIANCY?

A. It shows that they are *level tracts* of the nature of plains.

Q. How MANY of these comparatively level plains are there on the visible hemisphere of the Moon?

A. *Thirteen* well-marked plains have been observed.

Q. What is the GENERAL EXTENT of these plains in the Moon?

A. They vary in breadth from *two hundred to nearly eight hundred miles.*

Q. Are the lunar plains surrounded by RIDGES?

A. Yes; they are encompassed by *borders or ridges* somewhat like the cavities or craters.

Fig. 14 (Lunar Shadows) represents the appearance of one of these lunar plains as it may be seen on the eleventh day of the lunation, with its surrounding ridges and cavities. This plain has been called Mare Humorum. In *fig.* 18 is sketched the appearance of another lunar plain, (Mare Crisium,) as seen on the nineteenth day of the lunation. It will be observed that its elevated margin may be perceived projecting out quite into the dark part of the lunar sphere, and catching the Sun's rays before the neighboring plain can receive them. Mare Crisium is 280 miles in breadth, and 350 in length.

Q. What were these more level districts ONCE SUPPOSED to be?

A. They were once supposed to be *oceans and seas;* hence they have individually received the appellation of *Mare*—a sea.

Q. How can it be ascertained that they are NOT oceans and seas?

A. They are all of them covered by *fixed irregularities* of surface; whereas water, at that distance, would present a smooth, even aspect.

Q. Are there any CLOUDS floating round the lunar surface?

A. *No clouds* have ever been detected by the most powerful telescope.

Q. How is it known that the Moon has NOT ANY CLOUDS surrounding it?

A. The elevations and depressions on the Moon's surface are *always seen clearly,* provided our own atmosphere is cloudless.

Q. If a VAIL OF CLOUDS were floating round the Moon, what would be the EFFECT?

A. The irregularities of its surface would be at times *concealed,* though our own atmosphere were cloudless.

Q. Is there any WATER on the Moon?

A. In all probability there is *not.*

Q. Upon what grounds can it be concluded that the lunar surface is WITHOUT WATER?

A. When very faint stars are seen near the edge of the Moon, their light is *undimmed.*

Q. What would be the EFFECT if there were WATER on the lunar surface?

A. If there were water on the Moon, it must be converted into vapor where the Sun's heat is experienced continuously for half a month.

Q. Has the Moon any ATMOSPHERE?

A. The Moon cannot have any atmosphere of *sufficient density* to be worthy of the name of air. Some astronomers suppose the Moon has an atmosphere of *extreme rarity*, compared with that of the Earth.

Q. How can it be ASCERTAINED that the Moon is without an atmosphere?

A. The light of planets and stars *never varies* when passing near the edge of the Moon, as it would do if there were a lunar atmosphere.

Q. Is there, then, any DIFFUSED DAYLIGHT upon the Moon?

A. The bodies on the Moon's surface are either in *brilliant sunshine* or in *black darkness.* There is *no gradation of light* between the two, because the atmosphere of the Moon (if any) is not sufficiently dense to refract the rays of the Sun.

Q. Can there be any VARIATIONS of daylight on the Moon?

A. No; the sky must seem *black* at noonday, and the scorching beams of the Sun pour down upon a surface which is *never fanned by a breeze*, or *moistened by a shower*, or *screened by a cloud.*

Q. Is the absence of an atmosphere PERCEPTIBLE when the Moon is viewed through a telescope?

A. Yes; the want of the softening influence of atmospheric refraction is *at once discerned.*

Q. What APPEARANCE does this absence of an atmosphere present?

A. The illuminated portions of the Moon *glare* in the bright sunshine, while the obscured parts are covered with shadows traced in the *sharpest and boldest outlines.*

Q. Can there be any LIFE on the Moon's surface?

A. Certainly *no such life* as exists upon our globe.

SECTION II.

Jupiter's Satellites.

Q. What are the MINUTE BODIES which the telescope reveals as attendant upon Jupiter?

A. They are Jupiter's *satellites* or *attendant moons.* They are to Jupiter what our Moon is to us.

Q. How MANY attendant moons has Jupiter?

A. Jupiter has *four moons.*

"Beyond the sphere of Mars, in distant skies,
Revolves the mighty magnitude of JOVE
With kingly state, the rival of the Sun.
About him round FOUR PLANETARY MOONS,
On earth with wonder all night long beheld,
Moon above moon, his fair attendants dance."

Q. Do these moons REVOLVE around Jupiter?

A. Yes; they *move round* Jupiter as our Moon revolves round our Earth.

Q. Are the orbits of Jupiter's moons ELLIPTICAL?

A. Their orbits are almost circles, having a *very small* eccentricity.

Q. Do they revolve round the planet from WEST to EAST?

A. They do.

Q. Are the planes of Jupiter's satellites INCLINED to the plane of his orbit?

A. The planes of Jupiter's satellites coincide nearly, though not exactly, with the plane of the planet's orbit.

Q. WHEN and BY WHOM were the satellites of Jupiter discovered?

A. They were discovered in the year 1610 by Galileo.

Q. How do Jupiter's satellites APPEAR when viewed through the telescope?

A. They appear like *small stars* ranged nearly in a line with the planet's equator.

Q. What are the DIMENSIONS of Jupiter's satellites?

A. They are, all of them, *somewhat larger* than our Moon.

Q. How are the four satellites designated?

A. The one which revolves *nearest* to the planet is called the *first* satellite; the one next in order, the *second;* and so on.

Q. Which is the LARGEST of Jupiter's moons?

A. The *third* satellite from the planet is the largest, measuring 3580 miles in diameter, which is 440 miles greater than that of the planet Mercury.

Q. Which is the SMALLEST of Jupiter's satellites?

A. The *second* in order from the planet is 2190 miles in diameter, being *very little larger* than our Moon.

Q. Are these moons AS LARGE in comparison to the size of Jupiter as our Moon is, compared with the size of our Earth?

A. No; they are *much smaller* bodies, viewed relatively to the size of Jupiter, than our Moon is, compared with our Earth.

Q. What is the DIFFERENCE between the diameter of Jupiter's largest satellite and the planet itself?

A. The *largest* satellite has only one *twenty-fifth* part of the diameter of Jupiter, while our Moon has nearly *one-fourth* the diameter of the Earth.

Q. How FAR is the NEAREST satellite from the body of Jupiter?

A. The nearest satellite is about *two hundred and sixty-six thousand miles* from the planet.

Q. How FAR is the FARTHEST satellite from Jupiter?

A. The farthest satellite is nearly *a million and a quarter* of miles distant from Jupiter.

Q. How LONG does it require the first or nearest satellite to REVOLVE round Jupiter?

A. The first satellite revolves round its primary in *one day and eighteen hours.*

Q. In what TIME does the fourth or farthest moon revolve round its primary?

A. The fourth satellite revolves round Jupiter in rather less than *seventeen days.*

Q. What SIZE does the nearest satellite appear from Jupiter?

A. The first satellite must appear to the inhabitants of Jupiter a *little larger* than our Moon; the second and third appear *one-third less*, and the fourth about *one-fourth* as large as our Moon.

Q. Do the satellites of Jupiter REVOLVE on their axes as the Moon does?

A. All of them are supposed to *rotate* upon their axes in the *same time* in which they revolve round their primary: consequently, the inhabitants of Jupiter can never see but one hemisphere of each moon.

Q. Do the satellites of Jupiter suffer ECLIPSE as our Moon does?

A. Yes; by watching the moons of Jupiter, *eclipses* may be seen *resembling* those of our Moon.

Q. Do eclipses of Jupiter's moons occur MORE FREQUENTLY than with our Moon?

A. They do; the *three nearest* satellites suffer eclipse at *every revolution* round the planet.

Q. What important DISCOVERY have astronomers made by observing the eclipses of Jupiter's satellites?

A. The *aberration of light;** and that a ray of light travels at the rate of nearly *two hundred thousand miles* in a *second* of time. (*See Note* 21.)

> "By these observed, the RAPID PROGRESS finds
> Of LIGHT itself: how swift the headlong ray
> Shoots from the Sun's height through unbounded space!
> At once enlightening air, and earth, and heaven."

Roemer, a Danish astronomer, in 1675, discovered that light required *time* to travel through space. Before that time it was thought to be propagated *instantly.* Subsequently, Bradley confirmed Roemer's theory by the discovery of the aberration of light.

Q. Do the satellites of Jupiter exhibit the SAME PHASES which our Moon does?

A. They do; as the first satellite revolves about Jupiter in one day and eighteen hours, or in forty-two hours, in that *short space of time* it exhibits *all the phases* from a slender crescent to a full moon.

---

* See Part iii. chap. i. sec. i. div. iv.

Q. Why do the satellites of Jupiter MOVE SO MUCH more RAPIDLY in their orbits than our Moon does in hers?

A. Because the *attractive force* of Jupiter is so great, that if his satellites had not a *rapid projectile motion* to overcome his *centripetal force*, they would fall to the body of the planet.

(See centrifugal and centripetal forces, Part i. chap. i. sec. iii. div. ii.)

SECTION III.

The Rings and Moons of Saturn.

Q. What does the TELESCOPE REVEAL with regard to the planet Saturn?

A. It shows him encompassed by *broad rings*, and attended by *eight satellites* or moons.

"One moon to us reflects its cheerful light,
There, EIGHT attendants brighten up the night;
Here, the blue firmanent bedecked with stars,
There, overhead a lucid ARCH appears."

Q. What are the RINGS which encircle Saturn?

A. They are extremely *thin*, *opaque* bodies, which surround the planet.

Q. How is it KNOWN that these rings are OPAQUE?

A. Because they cast a *shadow* on the body of the planet on the side nearest to the Sun, and on the other side *receive* the shadow of Saturn.

Sir William Herschel was the first who discerned the shadow of Saturn's ring on the planet when the ring itself was invisible, having its thin edge turned towards us. Place one edge of a slip of paper against the wall, so that the other *edge* may be in a line with your eye; at a little distance, the edge or thickness of the paper would be invisible, being too minute to be distinguished; but its shadow, if the light were thrown on its upper or under surface, would be readily seen projected on the wall. Saturn's ring being so thin, could not be perceived through the telescope, yet the shadow it cast, being broad, could easily be distinguished on the body of the planet.

Q. How MANY RINGS has the planet Saturn?

A. One *outer* or *luminous ring*, and an *inner dark ring*, which reflects but little light.

Q. What is the NATURE of this outer or luminous ring.

A. It seems like an *opaque substance*, capable of reflecting light; and by the aid of good telescopes appears to be divided into *three separate rings*, the inner one of which is more luminous than the others. (*See Note* 22.)

Q. Of what NATURE is the inner dark ring?

A. It appears to be composed of matter *less opaque* than the luminous rings, and less capable of reflecting light. (*See Note* 23.)

Q. How are these rings SUSTAINED in their places, and prevented from FALLING on the body of the planet?

A. They rotate or *revolve very rapidly* round the body of Saturn. It is the *centrifugal* force arising from this rotation which sustains them in their position.

Q. What TIME do the rings of Saturn require to make ONE REVOLUTION?

A. The times of the revolutions of the different rings are not certainly known. But it is supposed they revolve in different periods; those nearest to the planet in all probability move with somewhat greater velocity than those more distant from it.

The rings are supposed to rotate in about the same time the planet performs a revolution on its axis.

Q. At what DISTANCE are Saturn's rings from the body of the planet?

A. The inner ring is about *nineteen thousand miles* from the surface of Saturn.

Q. What is the THICKNESS of the rings?

A. They are not more than from *one hundred to two hundred miles* in thickness.

Q. Of what USE are the rings of Saturn?

A. They *reflect the light* of the Sun; and being so much nearer to the planet than our Moon, and of such vast magnitude, they would tend to *enlighten* the planet by one *vast arch* of moonlight.

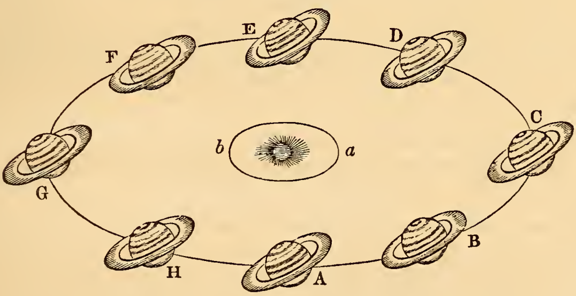
Q. Do the rings of Saturn always present the SAME APPEARANCE through the telescope?

A. No; sometimes they appear in the form of *an ellipse*, which contracts until it dwindles into a *straight line.*

Q. Does Saturn's ring always remain PARALLEL TO ITSELF during its revolution round the Sun?

A. It *does;* as may be seen in the following figure.

Fig. 65.



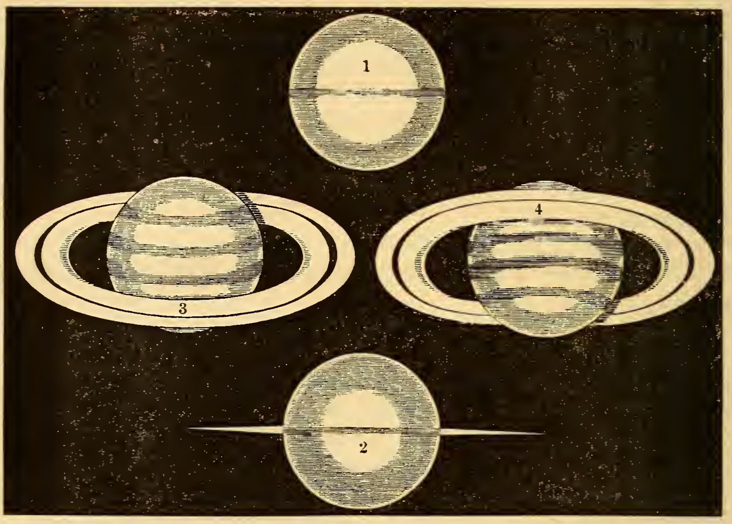
Let *a b* be the orbit of the Earth, and A B C, &c. represent Saturn in different parts of his orbit. At the point C, the ellipse appears the most open to an inhabitant of the Earth, and contracts until it comes to E, where it presents only a line to the eye of a spectator on the Earth; from E to G it opens again, and at G appears as broad as at C. From G it contracts, till at A it has only the appearance of a line; from A to C it again appears to open.

Q. How OFTEN do we LOSE SIGHT of Saturn's ring, owing to its plane being in the same line with our eyes?

A. *Twice* in each of Saturn's revolutions round the Sun; that is, once in nearly every *fifteen years.*

In the following figure, four of the different views of Saturn's ring are given: from the open ellipse to the disappearance of the ring.

Fig. 66.



No. 1 represents when the ring has disappeared, or when it is at the points A and E of *fig.* 65. No. 2 shows the ring as a mere line of light; No. 3 exhibits the upper side of the ring as when it is at C, and No. 4 the lower side of it, as when it is at G, in the same figure.

Q. How MANY attendant moons has the planet Saturn?

A. Saturn has *eight satellites* or moons.

Q. Can Saturn's moons be seen by telescopes of MODERATE power?

A. Only *one* of Saturn's moons is large enough to be seen by telescopes of moderate power. This moon is known by the name of Titan. (*See Note* 24.)

Q. Do Saturn's moons suffer ECLIPSES?

A. *They do;* but it requires *very powerful telescopes* to discern them.

Q. Has any RELATION been discovered between the PERIODS of any of Saturn's satellites?

A. Yes; Sir John Herschel discovered that the period of the revolution of the *first* satellite in order from the planet is *half* that of the *third;* and that the period of the *second* in order is *half* that of the *fourth.*

Q. In what TIME does the first satellite revolve round Saturn?

A. In about *twenty-two hours and a half*, and the third requires *double* that time, or *forty-five hours.*

Q. How LONG does the second satellite require to perform its journey round the primary?

A. The second satellite revolves about its primary in a little less than *thirty-three hours;* and the fourth requires *double* that time, or less than *sixty-six hours.*

Q. What is the distance of Saturn's FARTHEST SATELLITE from the planet?

A. It is situated at the distance of about *two millions three hundred thousand miles* from Saturn, or nearly *ten* times the distance of our Moon from us.

Q. What kind of APPEARANCE do the heavens present to the inhabitants of Saturn?

A. The celestial scenery on Saturn must be magnificent beyond description. The ring rolling round its primary, reflecting light from its surface similar to that of our Moon; besides which, eight moons exhibit their phases, from the slender crescent to the full orb.

Q. Are any of Saturn's moons NEARER to it than our Moon is to us?

A. Three of Saturn's moon's are *much nearer* to him than our Moon is to us.

Q. Do Saturn's moons exhibit PHASES like our Moon?

A. Yes. The satellite nearest to Saturn is not more than one-half as far from it as our Moon is from us; and in the course of *twenty-two hours and a half* exhibits *all the phases* which our Moon performs in a month.

A list of Saturn's moons, according to the nomenclature of Sir John Herschel, the dates of their discovery, and the names of their discoverers, is given below:

1. Mimas,	Sept. 17, 1789,	Sir W. Herschel.
2. Enceladus,	Aug. 19, 1787,	" "
3. Tethys,	March, 1684,	Dominic Cassini.
4. Dione,	March, 1684,	" "
5. Rhea,	Dec. 23, 1672,	" "
6. Titan,	March 25, 1655,	Huyghens.
7. Hyperion,	Sept. 18, 1848,	Bond and Lassell.
8. Japetus,	Oct. 1671,	Cassini.

Hyperion, the seventh satellite, has been recently discovered by Professor Bond, of Cambridge, Massachusetts, and on the same night by Mr. Lassell, of Liverpool.

SECTION IV.

The Moons of Uranus.

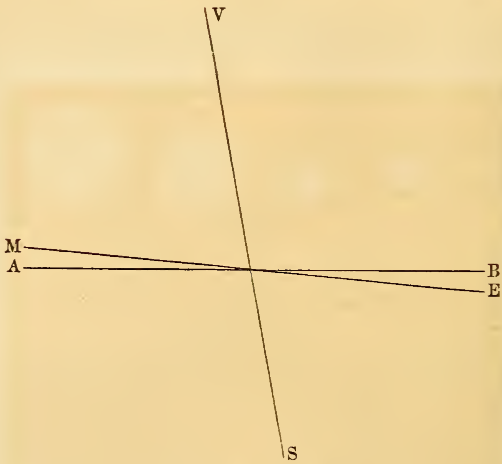
Q. How MANY satellites has the planet Uranus?

A. It is supposed to have *six* attendant moons; but owing to the great distance of the planet from us, four only can be detected by the most powerful telescopes, and under the most favorable circumstances.

Q. Are there any PECULIARITIES observed with regard to the motions of the satellites of Uranus?

A. Yes; they revolve round him in orbits *nearly perpendicular* to the plane in which the planet moves round the Sun; and unlike all the other known planets and satellites, which move from west to east, they move in a reverse direction, that is, from *east* to *west*.

Fig. 67.



Let A B represent the orbit of the Earth, the line M E will show the inclination of the orbit of our Moon to that of the Earth. Now, if A B represent the orbit of Uranus, the line V S will show the inclination of the orbits of his satallites, which is 78° 58′ to the plane of the ecliptic.

Q. Are the orbits of the moons of Uranus ELLIPTICAL, like those of the other planets and satellites?

A. No; the orbits of the moons of Uranus are *nearly circular.*

The moons of Uranus, according to Sir William Herschel, are *six* in number; but *four* only have been seen by Sir John Herschel, Mr. Lassell, and Otto Struve, namely:

1. *Ariel,*	which has a period of		2	days	12	hours.
2. *Umbriel,*	"	"	4	"	4	"
3. *Oberon,*	"	"	10	"	23	"
4. *Titania,*	"	"	13	"	11	"

SECTION V.

The Moons of Neptune.

Q. Has Neptune any SATELLITE?

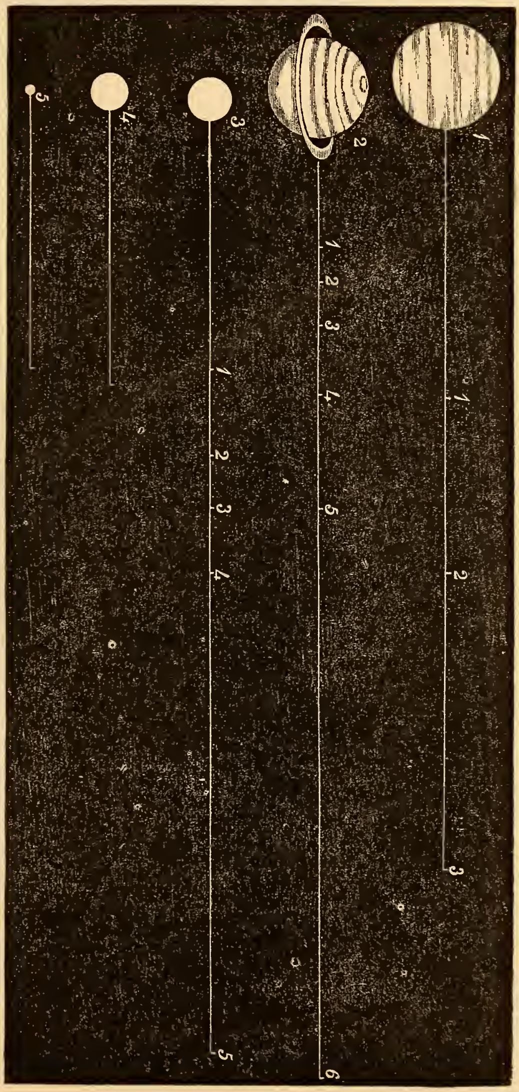
A. *One* attendant moon has been discovered as belonging to this planet, and it is believed that another has been detected.

Some astronomers have thought they have been able to distinguish a ring round this planet; but as yet no satisfactory observations have been made with regard to it.

In the following figure, No. 1 represents Jupiter and three of his moons, at their respective distances from their primary. One end of a string placed on the centre of the planet, and extended seven inches, would designate the distance of the orbit of the fourth and most distant satellite. No. 2 is Saturn, with the relative distances of the orbits of six of his satellites. One end of a string placed on the centre of Saturn, and extended seven inches, would reach the orbit of his seventh satellite; while it would require a string of sixteen inches to reach to the orbit of the eighth and most distant of Saturn's moons. No. 3 represents the planet Uranus, and his relative size with regard to Jupiter and Saturn. The orbits of five of his satellites are designated, but, for

want of space, the sixth must be shown by a string eleven inches in length, one end of which is placed at the centre of the planet, and the other extended its full length. No. 4 represents the planet Neptune and his first satellite. No. 5 is our Earth and Moon, drawn to the same scale.

Fig. 68.



CHAPTER VII.

Motion of the Earth.

Q. Does the Earth always remain in the SAME PART of space?

A. It does *not.* It is constantly *changing its position* with great velocity.

Q. How MANY motions has the Earth?

A. Its principal motions are *two*, the one *round its axis* from west to east, and the other *round the Sun.*

> ———"From west her silent course advance
> With inoffensive pace, that spinning sleeps
> On her soft axle, while she paces even
> And bears thee soft, with the smooth air along."—MILTON.

Q. What causes the Earth to MOVE ROUND THE SUN?

A. It is acted upon by *two forces*, which, when *combined*, cause it to revolve round the Sun.

Q. What are the TWO FORCES which act together to cause this motion of the Earth round the centre of the system?

A. The one is a power seated in the Sun, called the attraction of gravitation, or *centripetal force;* the other the *centrifugal force*, or the Earth's projectile motion.

> "And if each system in gradation roll,
> Alike essential to the amazing whole,
> The least confusion but in ONE, not all
> That system ONLY, but the WHOLE must fall.
> Let Earth unbalanced from her orbit fly,
> Planets and suns run lawless through the sky."—POPE.

SECTION I.

Diurnal Motions of the Earth.

Q. What EFFECT is produced by the rotation of the Earth on its axis?

A. It produces the succession of *day and night.*

A day in common language is the interval of time which elapses from the rising to the setting of the Sun. But astronomers reckon from noon to noon: thus, June 3, 20 hours *astronomical time,* would be June 4, 8 o'clock in the morning *civil time,* or according to the common reckoning.

Q. How can the rotation of the Earth produce DAYLIGHT and DARKNESS?

A. As the Earth revolves on its axis it always presents *one hemisphere* to the Sun's rays; and to the inhabitants of that part of the Earth turned towards the Sun it is *day.*

> "Blest power of sunshine! genial day!
> What balm, what life is in thy ray."—LALLA ROOKH.

Q. What causes the phenomena of SUNRISE and SUNSET?

A. As the Earth turns on her axis, to the inhabitants of that

point on her surface which is just receiving the first rays of the Sun, the Sun is just *rising;* while to the inhabitants of that part which is just receiving his last rays, he is *setting.*

Q. When is it MIDDAY?

A. When the centre of the Sun is on the *meridian of any place,* it is midday or noon to the inhabitants of that place.

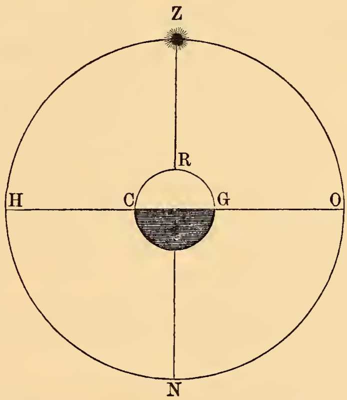
Q. When is it MIDNIGHT?

A. When the centre of the Sun is on the meridian of the observer extended into the *opposite hemisphere.* Thus, midnight is just *twelve hours* from noon.

It is midnight to us when it is noon or mid-day to our antipodes.

"Day takes his daily turn,
Rising between the gulphy dells of night,
Like whitened billows on a gloomy sea."—JOANNA BAILLIE.

Fig. 69.



Let G R C represent the Earth, which is revolving on her axis from G to R, R to C, and let the Sun be fixed in the heavens at Z; it will illuminate all that part of the Earth which is above G C. To the inhabitants at G, the western boundary of sunlight, the Sun will be just rising; and when, by the motion of the Earth, they arrive at R, it will be noon, while it will be setting when they arrive at C. As only one-half the heavens can be seen at any one time, the spectator at G will see the concave hemisphere Z O N; consequently, the Sun's place will be the eastern boundary of his horizon. When, by the rotation of the Earth, the observer at G arrives at C, the boundary of his horizon will be N H Z; consequently, the Sun will be in the western boundary of his horizon, and will appear to be setting.

Q. What is the HORIZON?

A. The horizon is that circle in the heavens which *bounds the view* on all sides, and which is greater or less as the observer is more or less elevated from the surface of the Earth.

Q. What is the horizon CALLED which bounds the observer's view on all sides?

A. It is called the *sensible horizon.*

Q. Is there any OTHER horizon except the sensible horizon?

A. There is. An imaginary line drawn through the *centre of the Earth,* parallel to the sensible horizon, and extended to the heavens, is also called a horizon.

Q. What is that horizon CALLED which is bounded by an imaginary line drawn through the centre of the Earth?

A. It is called the *rational horizon.*

In *fig.* 69, to an inhabitant at R, his rational horizon would be bounded by the line H O.

Q. What is that POINT of the horizon called which is OPPOSITE to an observer's face stationed north of the tropics, when he stands looking towards the Sun at noon?

A. To any observer stationed north of the tropics, that point of the horizon towards which the Sun is situated at noon, is called the *south point* of the horizon.

Q. What is that point of the horizon called which is directly BEHIND an observer stationed north of the equator, when he stands looking towards the south?

A. That point of the horizon which is directly opposite to the south, is called the *north* point of the horizon.

Q. Which are the EAST and WEST points of the horizon?

A. Those two points of the horizon which are *midway between* the north and south points.

Q. How are the east and west points of the horizon SITUATED with regard to each other?

A. Like the north and south points, the east and west points are *directly opposite* to each other.

Q. When an observer stands with his face to the south, in what DIRECTION are the east and west points with regard to his position?

A. The east is to his *left* hand, and the west to his *right* hand.

Q. What are these four points of the horizon CALLED?

A. They are called the *cardinal points* of the horizon.

Q. How far are the four cardinal points ASUNDER by angular measurement?

A. As the horizon is a circle, it must contain 360 degrees; and as the four cardinal points of the horizon are at equal distances from each other, it follows that the east, west, north, and south points must be situated 90 degrees, or a quarter of a circle, from each other.

Q. What is the ZENITH?

A. The zenith is that point in the heavens *immediately over the head* of the observer.

Q. What is meant by the AZIMUTH of a body?

A. In order to find the azimuth of a body, an imaginary line must be drawn from the zenith (that is, the point overhead) through the body, and extended until it touches the horizon. The *angular distance* between the *north* or *south points* of the horizon, and the point where the imaginary line *meets* the horizon, is the azimuth of a body.

Q. What is the azimuth of a heavenly body DUE WEST from the observer?

A. An imaginary line drawn from the zenith through the body would touch the west point of the horizon; now, the angular distance from the north or south points to the west point of the horizon is just 90 degrees; therefore the body must have an azimuth of 90 degrees.

Sir John Herschel says—"Azimuth *may* be reckoned eastward or westward from the north or south point, and is usually so reckoned to 180° either way. But to avoid confusion, and to preserve continuity of interpretation when algebraic symbols are used,

(a point of essential importance, hitherto too little insisted on,) we shall always reckon azimuth *from* the points of the horizon *most remote* from the *elevated* pole *westward,* (so as to agree in general directions with the apparent diurnal motion of the stars,) and carry its reckoning from 0° to 360°, if always reckoned positive, considering the eastward reckoning as negative."

Q. What is meant by a MERIDIAN?

A. The meridian of any observer is an imaginary line drawn from the north point of his horizon, through the zenith, to the south point of his horizon.

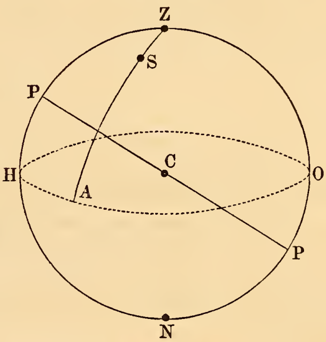
Q. What is meant by the ALTITUDE of a star or planet?

A. The *angular distance* of any heavenly body from the horizon is its altitude.

Q. How is this angular distance RECKONED?

A. An *imaginary line* is drawn from the zenith through the body, and extended to the horizon. The number of degrees measured on this imaginary line, from the point where it meets the horizon to the body, shows its *altitude.*

Fig. 70.



Let C be the place of the observer, H Z O N would represent the sphere of the heavens, the dotted circle H O the horizon, P P the poles of the celestial sphere, and Z the zenith of the observer.

Now, in order to find the altitude and azimuth of the star S, an imaginary line must be drawn from the zenith Z, through the star S, to the horizon. The arc of the horizon H A is its *azimuth,* and the angular distance from the point A to the star S is its *altitude.*

Q. Why do the heavenly bodies seem to move from EAST to WEST in the concave sphere of the heavens?

A. Because the Earth's surface on which the observer stands is carried along in the *opposite direction*, that is, from west to east, in consequence of the Earth's rotation.

Q. To what is the APPARENT MOTION of the heavens due?

A. The apparent motion of the heavens is owing to the *real motion* of the Earth in the opposite direction.

Q. How FAR do the heavenly bodies appear to have moved after the lapse of an hour?

A. The heavenly bodies pass through *fifteen degrees* of angular measurement in one hour; that is, through a quarter of a degree in one minute.

As the Earth revolves on its axis once in twenty-four hours, that is, through 360° in twenty-four hours, it must revolve through the twenty-fourth part of 360° in one hour. The twenty-fourth part of 360° is 15°, which is the angular distance the Earth moves in one hour.

Q. Did the ANCIENTS believe that the Earth revolves on its axis?

A. No; they conceived the Earth to be *stationary*, and the Sun and stars to revolve round it once in twenty-four hours.

As the Sun and stars are at such vast distances from us, they would be required to revolve with inconceivable rapidity to perform a diurnal rotation round the Earth.

Q. Why do the Sun and stars appear to MOVE around us?

A. It is owing to the *revolution* of the Earth on its *axis*.

Q. In what LENGTH OF TIME do the Sun and stars appear to move around us?

A. In the same time it takes the Earth to turn *once on her axis;* that is, once in twenty-four hours.

Q. Is the time which the Earth requires to perform a revolution on its axis INVARIABLE?

A. It is. La Place has shown that the length of the day has not varied the *hundredth part of a second* since the observations of Hipparchus *two thousand years ago.*

Q. Are the stars scattered all over the FIRMAMENT?

A. They *are.*

Q. Then why can we not SEE the stars in the daytime?

A. Because the Sun's light is so much more *powerful*, that it *obscures* the fainter light of the stars—

"Confounded and outdone
By the superior lustre of the Sun.'

Q. When can we SEE the stars?

A. When that part of the Earth on which we live is *turned away* from the Sun's rays, we can then see the stars.

Q. Can the stars ever be seen by the naked eye in the DAYTIME?

A. Yes. By descending the shaft of a *very deep mine*, the stars may be seen at noon as well as at night; or during the obscuration caused by a *total solar eclipse*, the brightest stars are visible.

By the aid of a telescope, stars are rendered visible even in the vicinity of the Sun; that is, when apparently near to the Sun's orb, though they are in fact immensely distant from, yet in the same direction with, him.

SECTION II.

Annual Motion of the Earth.

"Go! all the sightless realms of space survey;
Returning, trace the planetary way;
The Sun that in his central glory shines,
While every planet round his orb inclines;
Then at our intermediate globe repose,
And view yon stellar satellite that glows.
Or cast along the azure vault thine eye,
When golden day enlightens all the sky;
Around, behold Earth's variegated scene,
The mingling prospects and the flowery green,

The mountain's brow, the long-extended wood,
Or the rude rock that threatens o'er the flood;
And say, are these the wild effects of chance?
Oh! strange effect of reasoning ignorance!"—BOYSE.

Q. Does the Sun MOVE in the heavens?

A. No; but owing to the motion of the Earth round the Sun, he *appears* to move round the Earth?

If a person be seated in a boat on smooth water, and suffer himself to be carried along by the current, without the use of oars, he would not feel the motion of the boat. Now let him fix his eye on the shore, and all the objects appear to be in motion. Thus, the Sun, although stationary with regard to the Earth, appears to move.

Q. How LONG does it require the Earth to move round the Sun?

A. The Earth makes one revolution round the Sun in a *year;* hence it is called the *Annual Motion* of the Earth.

Q. How is it known that the Earth has completed ONE REVOLUTION after this lapse of time?

A. If the Sun be seen *in a line* with a fixed star at any particular day and hour, it will be found to be in a line again with the *same star* in one year; consequently, the Earth must have gone *once* round the Sun in that time.

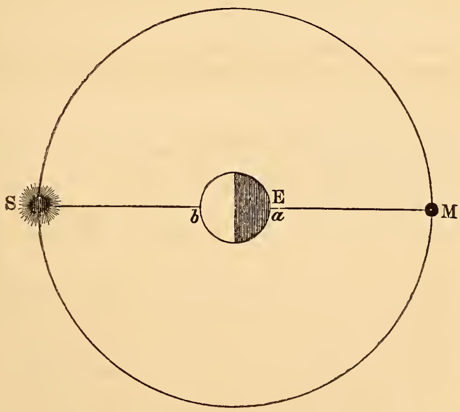
Q. How can it be ascertained that the Earth is BETWEEN certain stars and the Sun?

A. By observing that those stars are exactly on the meridian at midnight.

Q. If an observer look at a star on the meridian at midnight, how is he SITUATED with respect to the Sun?

A. The Sun is on the meridian to the inhabitants of the opposite side of the Earth.

Fig. 71.



Let S (*fig.* 71) represent the Sun's place in the great concave of the heavens, and M the place of some star directly opposite to the Sun in the apparent surface of the celestial sphere; let E represent the Earth half in daylight and half in darkness. Then it

is clear that the star must be exactly opposite the middle of the dark half of the Earth (that is, it must be on the meridian at midnight) when the Sun is exactly opposite to the other half of the Earth. So to the inhabitants at *a* it is midnight, while to those at *b* it is noon. Now, to show that the Sun is precisely on the opposite side of the Earth to the star, is to prove that the Earth is between the Sun and the star.

Q. What is the COMPLETE PERIOD of time called in which the Earth makes one revolution round the Sun?

A. It is called a *year.*

Q. With what VELOCITY does the Earth move in her orbit round the Sun?

A. The Earth moves at the mean rate of *sixty-eight thousand miles an hour* in her annual journey round the Sun.

Q. Does the Earth move with the SAME velocity in all parts of her orbit?

A. No. When she is in that part of her orbit *nearest* to the Sun, she moves with *greater* velocity than when she is at the point farthest from the Sun.

Q. Why does she move with GREATER velocity when at her perihelion, that is, when in that part of her orbit nearest to the Sun?

A. Because the Sun exercises a *greater attractive force* upon the Earth when she is nearest to him.

Q. If the Sun attracts the Earth more powerfully when in perihelion, why does she not FALL to the Sun?

A. Because by the *increased velocity* of her motion, her *centrifugal force* is also increased.

SECTION III.

The Seasons.

"These as they change, Almighty Father, these
Are but the varied God! The rolling year
Is full of Thee."—THOMSON.

Q. What produces the change of seasons?

A. The change of seasons is produced by the *Annual Motion of the Earth.*

Q. Upon what does the VARIETY of seasons depend?

A. Upon the *position* of the Earth with respect to the Sun, and also upon the *length* of the day and night.

Q. Are not the days and nights EQUAL all over the Earth?

A. No; they are of *unequal lengths* in different parts of the Earth.

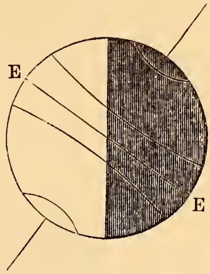
Q. Is there any PART of the Earth where the days and nights are of EQUAL lengths?

A. The days and nights are of equal lengths at the *equator.*

Q. Why are the days and nights ALWAYS of equal lengths at the Earth's equator?

A. Because the line which separates the illuminated from the dark hemisphere, must always divide the equator into *two equal parts.*

Fig. 72.



In *fig.* 72, E E represents the position of the equator as regards the light and dark hemisphere, in both the summer and winter seasons of the other parts of the Earth. It will be observed that any place upon the equator would be carried by the Earth's diurnal rotation half way through the circle in light and the other half in darkness.

Q. How are the different PORTIONS of the year made evident to our senses?

A. By the *changes* from heat to cold, and the reverse.

Q. What are the recurring HOT and COLD periods of the year called?

A. They are called *summer* and *winter* seasons.

Q. Are the DIFFERENT SEASONS to be attributed to the Annual Motion of the Earth?

A. Yes; it is the cause of the *various seasons.*

——"The seasons, months, and days,
The short-lived offspring of revolving time;
By turns they die, by turns are born.
Now cheerful Spring the circle leads
And strews with flowers the smiling meads;
Gay Summer next, whom russet robes adorn,
And waving fields of yellow corn;
Then Autumn, who with lavish stores
The lap of Nature spreads;
Decrepit Winter, laggard in the dance,
(Like feeble age oppressed with pain,)
A heavy season does maintain,
With driving snows and winds and rain,
Till Spring recruited to advance,
The varied year rolls round again."—HUGHES.

Q. Why is one part of the year WARMER than another?

A. Because all places on the Earth's surface are sometimes turned more *towards*, and at other times turned more *away* from, the Sun's *direct rays.*

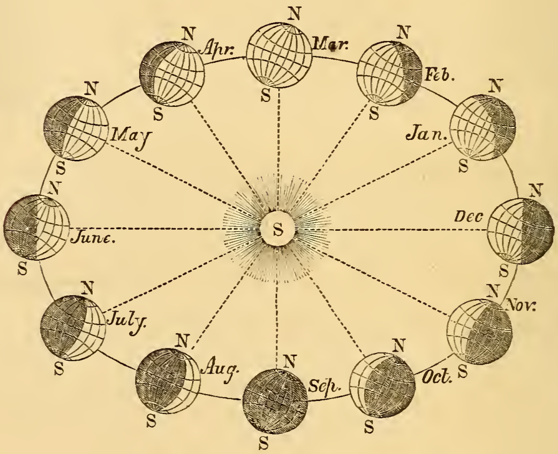
Q. Why are all places on the Earth's surface sometimes turned more TOWARDS, and sometimes more AWAY FROM, the Sun?

A. Because the Earth revolves round the Sun with the axis of its rotation held *sideways*, or *inclined*, instead of being perpendicular.

It will be seen by the following figure that the north pole of the Earth is turned away from the Sun in December, and consequently the greater part of the northern hemisphere is in darkness, the shortest day being the 21st of that month. As the duration of sunlight is so short, and as the Sun's rays fall *obliquely* on the northern latitudes, it is winter. As the Earth moves in her orbit her north pole is more and more turned to the Sun, till about the 21st of March, when it will be seen that both poles are enlight-

ened, the Sun being vertical at the equator. At this time the days and nights are equal, and spring commences. On the 21st of June the north pole is turned as much towards the Sun as the south pole was turned from it in December. At this period it is summer to the inhabitants of the northern hemisphere, and winter to those of the southern. About the 21st of September the Sun is vertical again at the equator, and the season of autumn commences.

Fig. 73.



Q. How much is the axis of the Earth INCLINED to the plane of her orbit?

A. The axis of the Earth is inclined *twenty-three degrees twenty-eight minutes* to the plane of her orbit.

Q. What is the Earth's ORBIT called?

A. It is called the *ecliptic.*

Q. What would be the EFFECT if the axis of the Earth were not thus INCLINED to the plane of her orbit?

A. That part of the Earth called the torrid zone would be *scorched*, while from forty or fifty degrees on each side of the equator to the poles an *unceasing winter* would reign.

> "He bid his angels turn askance
> The poles of Earth twice ten degrees and more
> From the Sun's axis."—MILTON.

Q. Does EVERY PORTION of the Earth's surface enjoy its summer at the same time?

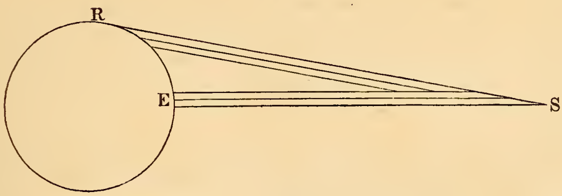
A. No; all that portion which is *nearest* to that pole which is turned towards the Sun is in the enjoyment of *summer*, while that portion in the vicinity to that pole *turned away* from the Sun is in *winter.*

Q. Why does that part of the Earth nearest to the pole which is turned TOWARDS the Sun experience the warmth of summer?

A. Because the Sun's rays fall more directly upon that portion

of the Earth's surface, and consequently exercise a greater heating power.

Fig. 74.

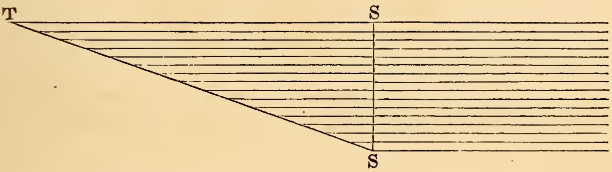


In the figure, the rays of the Sun are represented as proceeding from S; they fall perpendicularly upon E, the part of the Earth turned most towards the Sun, but obliquely upon R, the illuminated part of the Earth most remote from it.

Q. Why do the Sun's rays HEAT a surface upon which they fall, MORE, when they strike it PERPENDICULARLY, than when they strike it OBLIQUELY?

A. Because when they fall perpendicularly, they are spread over a comparatively *small space;* but when they fall obliquely, they are spread over a comparatively *larger one.*

Fig. 75.



In the figure, let S S represent the space on which a given number of rays fall perpendicularly; then S T would represent the space upon which the *same number of rays* would fall obliquely. But as S T is longer than S S, the same number of rays would be spread over a larger space in one case than in the other.

Q. Is the PERPENDICULAR manner in which the rays of the Sun fall on the Earth's surface in summer the ONLY cause of the heat of the season?

A. It is *not;* for in summer the days are always longer than the nights, and in winter they are shorter; consequently, in summer we have a longer duration of sunlight than in winter.

Q. Does the Earth ABSORB the heat of the Sun?

A. As long as the Earth's surface is *exposed* to the *Sun's rays,* it absorbs heat, just as a body becomes heated when held before a blazing fire.

Q. What is the EFFECT when turned away from the Sun's rays?

A. As long as the Earth is turned away from the Sun's rays, it continues to *radiate* the heat which it had previously received; consequently, the Earth's surface becomes heated during the long days of summer, and cooled during the long nights of winter.

"What prodigies can Power Divine perform
More grand than it produces year by year?
And all in sight of inattentive man!
Familiar with the effect, we slight the cause,
And in the constancy of Nature's course,
The regular return of genial months,
And renovation of a faded world,
See naught to wonder at."—Cowper.

Q. On what PART of the Earth do the Sun's rays fall perpendicularly?

A. The Sun's rays can only fall perpendicularly upon the Earth's surface *between the tropics.*

Q. Why are the Sun's rays perpendicular ONLY to those places situated within the tropics?

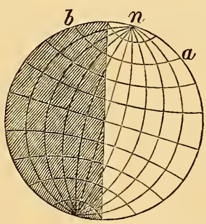
A. Because the axis of the Earth being *inclined* only *twenty-three degrees twenty-eight minutes*, the Sun is vertical only to places situated *within* that distance of the equator, the boundaries of which space are the tropics of Cancer and Capricorn.

The Sun is always vertical to some place *within* the tropics, and to no place *beyond* them.

Q. Why are the days LONGER than the nights to all places where it is SUMMER?

A. Because the pole nearest to those places is turned quite into the hemisphere of sunlight; and consequently, all places which are not 90° (or a quarter of the Earth's circumference) from the enlightened pole, are more than half the time of the Earth's rotation in sunlight, and less than half that time in darkness.

Fig. 76.



In the figure, let *a* represent the situation of Newfoundland upon the Earth's surface in the summer season, with *n* the northern extremity of the Earth's axis, turned quite into the hemisphere of sunlight; and let the line *a b* represent the parallel of latitude on which Newfoundland is situated. It will be observed that more than half that circle of diurnal motion lies in sunlight, and less than half of it in darkness.

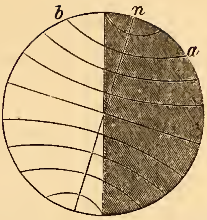
Q. When it is SUMMER to the inhabitants of the southern hemisphere, what SEASON is it in the northern hemisphere?

A. To the inhabitants of the northern hemisphere it is *winter* when it is *summer* in the southern hemisphere, and *vice versâ.*

Q. Why are the NIGHTS of winter longer than the DAYS?

A. Because the pole nearest to us is then turned quite into *darkness;* and, consequently, all places which are not 90° (that is, a quarter of the Earth's circumference) from that pole, are more than half the time of the Earth's rotation (that is, more than twelve hours) in darkness, and less than half the twenty-four hours in sunlight.

Fig. 77.



Let *a* (*fig.* 77) represent the position of Newfoundland upon the Earth's surface in the *winter* season. As the northern extremity of the Earth's axis is not illuminated by the Sun, those places in high northern latitudes must have but little daylight in the twenty-four hours. It will be seen that the parallel *a b* is much more than half in darkness; consequently, at Newfoundland, the days in winter must be much shorter than the nights.

Q. Does the length of the days at the poles VARY very much?

A. During the summer, in the northern hemisphere, places near the north pole are in *continual sunlight*—the sun never sets to them; while during that time places near the south pole never see the sun. And when it is summer in the southern hemisphere, and the sun shines on the south pole without setting, the north pole is entirely deprived of his light.

Q. Is there any part of the year when the days and nights are of EQUAL LENGTH all over the Earth?

A. Yes; on the 21*st of March* and 21*st of September* the days and nights are of equal length.

Q. Why are the days and nights of EQUAL LENGTH all over the earth in March and September?

A. Because both poles are on the *margin* which separates the light from the dark hemisphere; and consequently every place is carried by the Earth's rotation through a circle, which lies half in the light and half in the dark hemisphere.

Q. How LONG is the longest day at the poles?

A. At the poles there is but *one day* and *one night* in the year; for the Sun shines for six months together on one pole, and the other six months on the other pole.

Q. Is the Earth's orbit CIRCULAR?

A. No; it is slightly *elliptical.*

Q. Are we NEARER to the Sun in summer than in winter?

A. No; we are nearer to the Sun in *December* than we are in June.

Q. How is it KNOWN that we are farther from the Sun in June than in December?

A. It is known—1. Because our summer, or the time between the vernal and autumnal equinoxes, is nearly *eight days longer* than our winter, or the time between the autumnal and vernal equinoxes.

2. The Sun's *apparent diameter* is *greater* in our *winter* than in our summer; and as the apparent diameter of objects increases as the distance is diminished, it follows that the Sun is nearer to us in our winter than in our summer. (*See Note* 25.)

Q. Has the ELLIPTIC FORM of the Earth's orbit any influence in producing the variation of temperature corresponding to the difference of seasons?

A. The ellipticity of the Earth's orbit has but *trifling influence* on the difference of seasons.

Q. Is HEAT, like light, EQUALLY DISPERSED from the Sun in all directions?

A. It is.

Q. Where is the PERIHELION POINT of the Earth's elliptical orbit SITUATED?

A. Nearly at the place of the *winter solstice.*

Thus the Earth is in perihelion, or that point of her orbit nearest the Sun, at the winter solstice, or about the 21st of December; at which time it is midwinter in the northern hemisphere, and summer in the southern.

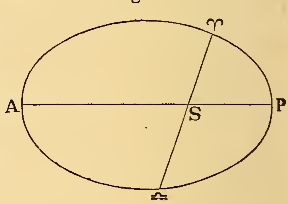
Q. Then, as the orbit of the Earth is elliptical, is there not a GREATER DEGREE of HEAT experienced in the southern hemisphere when we are in perihelion, or nearest to the Sun, than in the northern hemisphere when we are in aphelion?

A. No; an equilibrium of heat is generally maintained in both hemispheres.

Q. How is this equilibrium of heat MAINTAINED?

A. The Earth moves with greater rapidity in that part of its orbit nearest to the Sun than in that part more remote from it.

Fig. 78.



Let S represent the Sun's place in one of the foci of the Earth's elliptical orbit, A ♈ P ♎. A is the aphelion, or farthest point from the Sun, and P the perihelion, or nearest point to it. As the planet moves from A to P its velocity will always be increasing, because it is drawing nearer and nearer to the Sun. But from P to A it will continually be decreasing in velocity; therefore it moves through one-half of its orbit in nearly the same time in which it revolves through the other half.

CHAPTER VIII.

Time.

"When yonder spheres sublime
Pealed their first note to sound the march of TIME."

Q. What is TIME?

A. Time is a *degree of duration* marked by periods or measures, chiefly established by motions of the heavenly bodies; as a year, a month, a day, &c.

Q. What NATURAL OCCURRENCE is taken as the most convenient measure for estimating the lapse of time?

A. The Earth's *rotation on its axis.*

Q. Why is the Earth's rotation on its axis the BEST AVAILABLE unit or standard for the measurement of time?

A. Because the Earth's rotation is the *most equable and uni-*

form motion in nature; every revolution on its axis being performed in *exactly the same space of time.*

Q. How is time DIVIDED?

A. Into *years, months, weeks, days, hours, minutes, and seconds.*

Q. How many KINDS of time are there?

A. There are *two kinds* of time noted by astronomers: viz. *sidereal* and *solar* time.

Q. What is SIDEREAL TIME?

A. Time measured by observing the apparent motions of the *stars.*

Q. What is SOLAR TIME?

A. Time measured by observing the apparent motion of the *Sun.*

Q. How is it KNOWN when the Earth has COMPLETED one revolution upon its axis?

A. It is noticed that the spot on which the observer stands has come once again *between the Earth's axis* and *some well-known star.*

Q. What is this UNIT of time CALLED in which the Earth completes one revolution upon its axis; that is, if a well-known star be on the meridian, till it comes on the meridian again?

A. It is called a *sidereal day.*

The interval between two successive passages of a star over the meridian of any place is called a *sidereal day.*

Q. What is that UNIT of time CALLED in which the Earth, by revolving on its axis, brings the SUN from the meridian of an observer to that meridian again?

A. It is called a *natural* or *solar day.*

Q. What is the LENGTH of a sidereal day?

A. The sidereal day consists of *twenty-three hours, fifty-six minutes, and four seconds.*

Q. What is the length of a NATURAL or SOLAR day?

A. The solar day consists of *twenty-four hours.*

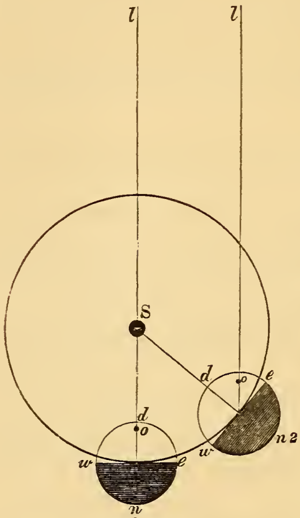
Q. What is the reason of this DIFFERENCE in the LENGTH of a sidereal and a solar day?

A. It is caused by the fact that any given spot on the Earth's surface does not arrive between the Earth's axis and the Sun a second time, *so soon* as it is again between the Earth's axis and a fixed star.

Q. Why is it that a given spot on the Earth's surface does not arrive a second time BETWEEN THE EARTH'S AXIS and the SUN, so soon as it does a second time between the Earth's axis and a STAR?

A. This is because the Earth is *moving round the Sun*, and is at the same time revolving on its axis.

Fig. 79.



Let S (*fig.* 79) represent the Sun, and 1 2 the the distance through which the Earth has moved in its orbit, when it has completed one revolution on its axis, in the direction *w n e d*, known by some given point *o*, having again come under the perpendicular line *l o*, representing the direction in which some star is viewed. Let it be remembered that the fixed stars are at such immensely great distances from us, that the two lines, *l o*, *l o*, will make no perceptible angle. It will be seen that in the position 2 the spot *o* is no longer opposite to both the Sun and the star, as it was in the position 1. The spot *o* will then have to turn on till it comes to *d* before it is again opposite to the Sun. The time which it takes to move from the line *l o* to *d* is the difference between a solar and a sidereal day.

"Watch with nice eye the Earth's diurnal way,
Marking her SOLAR and SIDEREAL DAY;
Her slow nutation, and her varying clime,
And trace with mimic art the march of TIME."—BOTANIC GARDEN.

Q. Is the solar day, like the sidereal day, ALWAYS of ONE LENGTH?

A. It is *not*. Some solar days are *much longer* than others, when measured by the apparent return of any given spot on the Earth's surface to a position between the Earth's axis and the Sun's centre.

Q. Why are some solar days LONGER than others?

A. Because the Earth *moves faster* in those parts of its orbit nearer the Sun, than in those the farthest from it.

Q. Why is the solar day taken for the COMMON RECKONING of time, since it is so much LESS CONSTANT as a measure than the sidereal day?

A. Because its middle is marked out conveniently by the *middle of daylight*. It is obviously convenient to have days and nights falling regularly amid the ordinary occupations of life. (*See Note* 26.)

Q. Do the common clocks that keep solar time follow the Sun's IRREGULARITIES?

A. No; common clocks are made to go, not by *apparent* solar time, but by what is called *mean* solar time.

Clocks regulated by the stars give *sidereal* time, and are used in astronomical observations; one revolution of the clock through twenty-four hours represents one apparent revolution of the starry sphere. When the clock shows 0*h.* 0*m.* 0*s.* the first point of Aries is on the meridian; and this being the point from which right ascension is reckoned, the time by the sidereal clock is always the right ascension of such stars as are passing

the meridian above the pole at the moment. Wherefore, by noting the time when a star is in this position, we have its distance from the first point of Aries.

Q. What is meant by APPARENT time?

A. Apparent time is measured by the *apparent* motion of the Sun in the heavens, or by a good sun-dial.

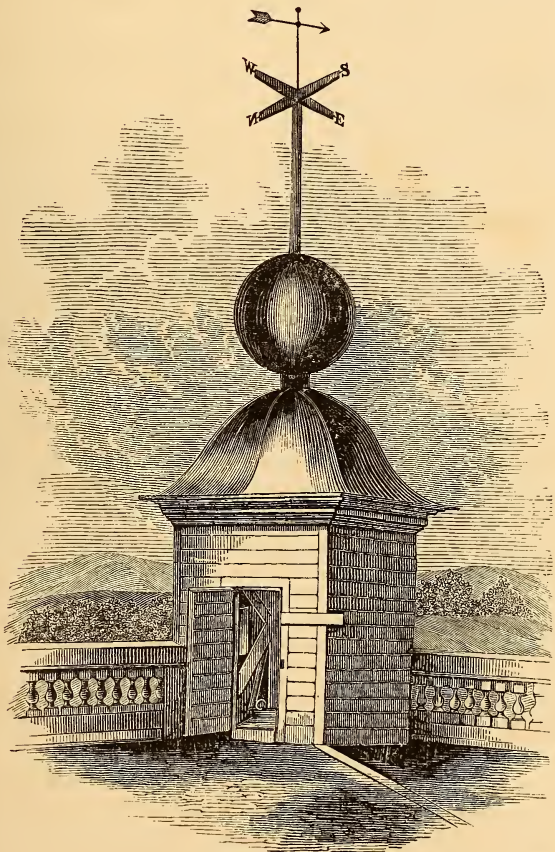
Q. What is MEAN time?

A. Mean time is measured by a *well-regulated clock*, that goes without variation, measuring twenty-four hours from noon to noon.

Q. How is mean time RECKONED?

A. By the *average length* of all the solar days throughout the year.

Fig. 80.



This is the period of time called a *civil day*, which consists of twenty-four hours, beginning at midnight. An exact knowledge of time is of the highest importance in navigation. The sailor endeavors to find, before he sails, how much his chronometers may vary from the true time, so as to be enabled to correct the error when at sea. For this purpose many seaports have a signal to indicate the moment of one o'clock. A ball is

attached to a mast or tower in some open situation, and at five minutes before one, the ball rises to the top; the moment it is one o'clock, the ball leaves the top of the mast. The figure represents the ball on the top of the observatory at Greenwich. The error in letting off this ball is less than two-tenths of a second.

Q. What is the EQUATION OF TIME?

A. It is the *difference* between *mean* and *apparent* time; that is, the *difference* of time as shown by a *well-regulated clock* and a *true sun-dial.*

As apparent time is sometimes greater and sometimes less than mean time, it follows that in some parts of the year they must coincide. This happens at present about the 15th of April, the 15th of June, the 1st of September, and the 22d of December.

Q. What is a YEAR?

A. The period that is marked by the Sun's being *vertical* a second time at one and the same *tropic.*

Q. What is the year called that is measured by the Earth moving so as to bring the Sun vertical a SECOND TIME to the same tropic?

A. It is called the *tropical* year.

Q. Has the Earth revolved COMPLETELY ROUND the Sun in a tropical year?

A. No; the Earth requires *twenty minutes and twenty seconds longer* to make one complete revolution round the Sun than it does to cause the Sun to appear vertical a second time at either of the tropics.

Q. How is it KNOWN when the Earth has accomplished one complete revolution round the Sun?

A. The Earth is known to have completed one revolution round the Sun, when it has again arrived between the *Sun's centre* and some *marked star.*

Q. How is it known when the TROPICAL year is completed?

A. The tropical year is completed when the Sun has returned a second time to the same equinoxes or solstices; which apparent revolution of the Sun is caused by the real motion of the Earth round that luminary.

Q. What is the period called in which the Earth arrives again to a station BETWEEN the SUN and the SAME STAR?

A. It is called a *sidereal year.*

Q. How LONG is the sidereal year?

A. The sidereal year is equal to 365 days, 6 hours, 9 minutes, and 9 seconds.

Q. What is the LENGTH of the tropical year?

A. The tropical year is equal to 365 days, 5 hours, 48 minutes, and 49 seconds.

Q. What causes this DIFFERENCE between the sidereal and tropical year?

A. It is caused by the fact that the axis round which the Earth rotates does not always continue in the same *precise* direction in space, but vacillates a little as it revolves.

Q. What is the meaning of the statement, that a tropical year consists of 365 days, 5 hours, 48 minutes, and 49 seconds?

A. It is meant that in that time the Earth has revolved *round*

its own axis 365 times, and as near a quarter of another time as 5 hours, 48 minutes, and 49 seconds is to 6 complete hours.

Q. Since the Earth does not turn on its axis ANY EXACT NUMBER of times in a year, how is it that every year begins with the COMMENCEMENT of a DAY?

A. During *three years* the superfluous hours and minutes by which 365 days are exceeded are disregarded; but on *every fourth year* they are put together and reckoned as an additional day, properly belonging to that year.

Q. How many days does EACH FOURTH YEAR consequently contain?

A. Each fourth year contains *three hundred and sixty-six days.*

Q. What is the LONG year CALLED, which contains 366 days?

A. It is called *leap year.*

Leap year is also called *Bissextile.* The Romans inserted the intercalary day between the 23d and 24th of February; the 23d of February in their calendar was called *sexto calendas Martii,* the sixth of the calends of March; and the intercalated day was called *bis sexto calendas Martii,* the second sixth of the calends of March; from whence our intercalated year is called *Bissextile,* or leap year.

Q. To what PART of the leap year is the 366th day added?

A. It is placed at the *end* of the shortest month; that is, at the *end of February;* consequently, every leap year has a 29th day of February. (*See Note* 27.)

Q. Is there any RULE whereby we may know what year is leap year?

A. It is known by dividing the *number of the year by four*, and if there be no remainder, it is leap year; the year 1870, when divided by 4, leaves a remainder of *two;* therefore, it must be the second year after leap year.

"Divide by 4, what's left shall be
For leap year, 0; for past, 1, 2, 3."

Q. Does the insertion of a leap year after every third common year, make the reckoning by solar days and tropical years EXACTLY CORRESPOND?

A. No, *not exactly.* It would do so if the tropical year consisted of 365 days and 6 hours *precisely;* but as it wants 11 minutes and 11 seconds of completing the 6 hours, the insertion of one day in every four years does not make the reckoning exactly correspond.

Q. How is this error REMEDIED?

A. By inserting a day in every year divisible by *four* and not divisible by a hundred, and also by inserting a day in every year divisible by 400.

Q. What is the CONSEQUENCE of this reckoning not corresponding exactly?

A. The consequence is, that there is an error of one day too many in every *three thousand six hundred years.*

Q. How is this error CORRECTED?

A. To correct this error, a day is always *left out of those leap years* whose remainder is exactly divisible by *four thousand without a remainder.*

Q. Does this correction REMEDY the error?

A. This error does not amount to an entire day until after the lapse of *one hundred thousand years.*

Q. When it is 12 o'clock or noon at Washington, is it noon at ALL PLACES in the United States?

A. No; it is noon to such places only as are on the *same meridian* as Washington.

Q. Suppose, then, an eclipse, or other astronomical observation, to be made at Washington and at Philadelphia by different persons, and the time at both places noted, would their time be the SAME?

A. No; the time would be a *little later* at Philadelphia, because it is a little farther *east.*

Q. What is meant by a CYCLE?

A. A periodical space of time, in which the same revolutions of the heavenly bodies *return again* to the *same days* of the week and month.

Q. What are the PRINCIPAL cycles, and what is their USE?

A. The principal cycles are the cycle of the *Sun* and the cycle of the *Moon;* they were invented for measuring the periodical motions of the heavenly bodies, and for obtaining a more exact *computation of time.*

Q. What is meant by a CYCLE of the SUN?

A. A revolution or period of *twenty-eight years;* at the expiration of which the days of the month *return again* to the same days of the week.

Q. What is a cycle of the Moon?

A. A cycle of the Moon consists of a period of *nineteen years;* after which the various aspects of the Moon are nearly the same as they were on the same days nineteen years before. (*See Note* 28.)

This cycle was adopted on the 16th of July, B. C. 433, by Meton, an Athenian, and is also known by the name of the *Metonic* cycle. The period of seventy-six years, or four Metonic cycles, was invented by Callippus, and is hence called the Callippic period.

CHAPTER IX.

The Ecliptic and Zodiac.

Q. What is the ECLIPTIC?

A. The ecliptic is an imaginary great circle in the heavens, through which the Sun *appears* to move once a year, but which is *really* the *path* which the Earth describes around the Sun.

Q. What is the EQUATOR?

A. The equator is an imaginary circle situated *equidistant from the poles*, and which divides the Earth into two hemispheres—the northern and the southern.

Q. What is the EQUINOCTIAL line?

A. The equinoctial is the plane of the equator *extended to the heavens*, and is sometimes called the *celestial equator.*

Q. Is the ecliptic PARALLEL to the equinoctial?

A. No; it is inclined about 23° 28′ to the equinoctial.

Q. Where is the ECLIPTIC to be found in the heavens?

A. *Half* of the ecliptic line is *north* of the equinoctial, and *half* of it *south* of the equinoctial.

Q. The equator of the heavens, or equinoctial, makes an angle with the ecliptic of 23° 28′: what is this angle CALLED?

A. This angle is called the *obliquity* of the ecliptic.

Q. What are the EQUINOXES?

A. The *two points* where the celestial equator is *intersected* by the ecliptic are called the equinoxes.

Q. What are the SOLSTICES?

A. Those *two points* on the ecliptic where the Sun is at his greatest distance *north* or *south* of the equator.

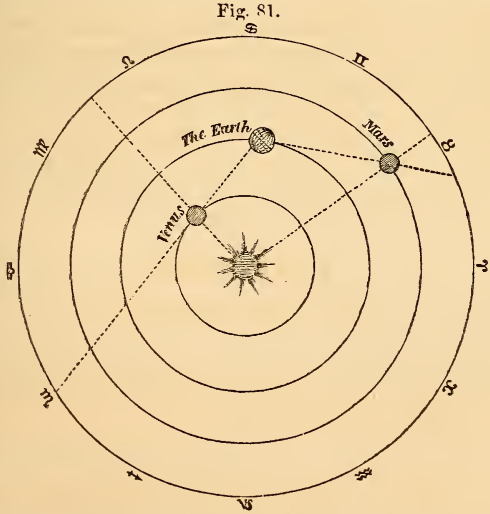
Q. What are the COLURES?

A. Two imaginary circles or meridians, one of which passes through the *equinoctial points*, and is called the equinoctial colure; the other passes through the *solstitial points*, and is called the solstitial colure. (*See Note* 29.)

Q. What is meant by HELIOCENTRIC and GEOCENTRIC place of a planet?

A. The heliocentric place is the point it occupies as seen from the *Sun;* the geocentric place, the point it occupies as seen from the *Earth.*

Fig. 81.



In the figure, the heliocentric place of Venus is in Leo, whereas the geocentric place is in the beginning of Scorpio. The heliocentric place of Mars is in Taurus, and the geocentric place in Aries.

Q. What is the ZODIAC?

A. An imaginary zone or belt extending around the heavens. It is sixteen degrees broad, through the middle of which is the ecliptic.

Q. What is the MEANING of the word zodiac?

A. It is derived from a Greek word signifying an *animal*, because the ancients represented each *sign* of the zodiac by some animal.

Q. How MANY SIGNS are there in the zodiac?

A. There are twelve signs in the zodiac, the signs and Latin names of which are as follows:—

♈ Aries.	♎ Libra.
♉ Taurus.	♏ Scorpio.
♊ Gemini.	♐ Sagittarius.
♋ Cancer.	♑ Capricornus.
♌ Leo.	♒ Aquarius.
♍ Virgo.	♓ Pisces.

But in the following lines the English names are used, which will be more easily remembered, as well as the order in which they stand:—

"The RAM, the BULL, the HEAVENLY TWINS,
And next the CRAB the LION shines,
The VIRGIN and the SCALES;
The SCORPION, ARCHER, and SEA GOAT,
The MAN that holds the WATERING POT,
And FISH with glittering tails."

Q. What is meant by a SIGN of the zodiac?

A. Every circle is divided into 360 degrees. Now, for convenience, the zodiac is divided into *twelve* equal parts, each of which, therefore, contains the *twelfth part* of 360 degrees; that is, *thirty* degrees. These twelve parts are denominated *signs*.

Q. Is there any thing REMARKABLE to be observed with regard to the zodiac?

A. The zone known as the zodiac is remarkable from its being the area or space within which the apparent motions of the *Sun*, *Moon*, and *all the planets* (except some of the asteroids) are confined.

All the planets, (except some of the asteroids,) as well as the Sun and Moon, are to be found in this space called the zodiac, which extends eight degrees on each side of the ecliptic.

Q. WHY are the planets and Moon to be found in that place called the zodiac?

A. Because their orbits are not *inclined* more than *eight* degrees to the ecliptic; therefore the boundaries of the zodiac are the extreme limits of their motions.

The Sun is always in the zodiac, because the ecliptic is his apparent path.

Q. How is the zodiac MARKED on the artificial globe?

A. Each sign is marked by the picture of some *animal*, *person*, or *figure*, because the ancients imagined the stars were grouped so as to form resemblances to such objects.

CHAPTER X.

Tides.

"The ebb of tides, and their mysterious flow,
We, as art's elements, shall understand."—DRYDEN.

Q. Why does the Moon move ROUND THE EARTH?

A. Because the Earth's mass attracts the Moon's mass; the Moon is also under another influence, called the centrifugal force, which, combined with the Earth's attraction, retains it in its orbit.

Q. Does the SUN'S MASS also influence the Moon's mass?

A. Yes; the Moon is attracted *by the Sun* as well as by the Earth.

Q. How is the SUN'S ATTRACTIVE INFLUENCE over the Moon made manifest?

A. By certain perceptible *irregularities of movement* which the Moon suffers.

Q. Does the Moon's mass ATTRACT THE EARTH'S MASS, as well as suffer its attraction?

A. It *does;* but as the Moon's mass is 80 times *less* than the Earth's mass, the Moon's attractive power is also 80 times less than that of the Earth.

Q. Is the attraction of gravitation UNIVERSAL?

A. Yes; the attraction of gravitation is *universal,* being present in *all material bodies.*

Every ponderable substance attracts every other ponderable substance in nature.

Q. How is the attraction of the Moon's substance for the Earth's substance manifested?

A. By the *swelling* of the waters of the ocean up towards the Moon.

"Attractive Power! whose mighty sway
The ocean's swelling waves obey;
And mounting upward, seem to raise
A liquid altar to thy praise."

Q. What is the DIFFERENCE between the movements, as a WHOLE, of solid bodies and fluid bodies?

A. Solid bodies can only move in a *mass;* but fluid bodies can be made to surge hither and thither, independently of any motion in the entire mass. Fluids are distinguished from solids by this power which their particles possess of moving about freely among each other.

Q. What is the SWELLING UP of the water towards the Moon called?

A. It is called a *tide* or *tidal wave.*

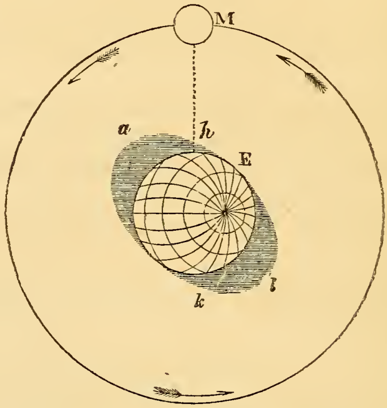
Q. Does the tidal wave rise highest on the part of the Earth's surface that is NEAREST to the Moon?

A. Not *exactly on that part.* The tidal wave rises highest on

a portion of the Earth's surface that has been a little *removed* from this position by the progress of the *Earth's rotation.*

This is called the *lagging* of the tides, which is illustrated by the following figure.

Fig. 82.



Suppose that the Earth E is turning round in the direction *h a k l*, (*fig.* 82,) the highest point of the tidal wave, caused by the Moon's attraction, lies not at *h*, but at *a*; and the opposite wave is in the corresponding position, as at *l*.

Q. Why does not the apex of the tidal wave fall on the part of the Earth's surface that is NEAREST to the Moon?

A. Because the rising of the water is *a gradual process*, and requires time for its accomplishment after the influence which causes it has come into operation.

Q. Why does not the water move INSTANTANEOUSLY into the position which the Moon's attraction draws it?

A. The *inertia* of the particles of water, and their *friction* against each other, combine to prevent their moving instantly into the position which the Moon's attraction strives to place them.

On account of the inertia of the waters, the tidal wave is not directly under the Moon, but under a meridian 30° eastward of it, in the hemisphere nearest the Moon, as well as on the opposite half of the Earth. On the west side of this great wave the tide is flowing; on the east it is ebbing; and on the meridian, 90° distant, it is low water.

Q. Does the swell of the tidal wave always hold the SAME POSITION on the Earth's surface?

A. No; the tidal wave *sweeps along* over the surface of the ocean, and having passed round the Earth arrives again at the spot from which it started, after an interval of *twenty-four hours and fifty minutes.*

Q. Why does the tidal wave of the ocean SWEEP ROUND the Earth's surface?

A. Because *fresh portions* of the surface of the ocean are continually passed in succession before the moon, in consequence of the Earth's rotation on her axis.

More properly, the Earth, rather than the wave, revolves.

Q. But the Earth turns on its axis once in twenty-four hours: why, then, is the swell of the tidal wave FIFTY MINUTES longer before it recurs at any given place?

A. Because during the twenty-four hours which the Earth has been turning on its axis, the *Moon has advanced* so far in her orbit, that the Earth must revolve fifty minutes longer before the same spot can be *directly under her influence* again.

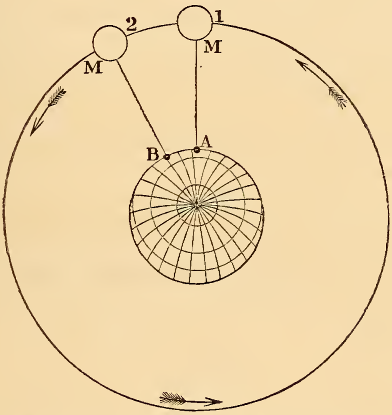
Q. If the Moon be observed to be over some fixed object, such as a chimney, on one night at a certain hour, will it be over the chimney on the next night at the SAME HOUR?

A. No; it will be found to hold the same position about *fifty minutes later* on the following evening.

Q. Why is the Moon LATER in arriving at the same position on the following evening?

A. Because when the Earth arrives into the same position, the Moon has *moved* in her orbit so far, that the Earth must rotate *fifty minutes* before it will bring the chimney into the same situation with regard to the Moon.

Fig. 83.



In the figure let M represent the Moon, moving in her orbit in the direction of the arrows. On a given day the Moon is vertical to a spot on the Earth's surface marked A. After a lapse of twenty-four hours the point A will have returned to the same position, but the Moon will have moved in her orbit from one to two; consequently, it would be vertical at a point on the Earth marked B. It will be seen that the observer at A will not see the Moon on his meridian until the Earth shall have revolved from A to B, which would require about fifty minutes.

Q. Does only ONE TIDAL WAVE sweep over the ocean's surface, in each interval of twenty-four hours and fifty minutes?

A. No; *two* high tides occur in that interval, each following the other at a period of twelve hours and twenty-five minutes.

"Alternate tides in sacred order run."—BLACKMORE.

Q. Why are there TWO tidal waves in twenty-four hours and fifty minutes?

A. Because the water is attracted on the side of the Earth *next to the Moon*; and it is *left* on the other side of the Earth, because

the Moon attracts the Earth more than the waters which cover the hemisphere opposite to the Moon.

Q. Why is there a SECOND HIGH TIDE on that part of the Earth's surface which is farthest from the Moon?

A. Because the water there is *less influenced* by the Moon's attraction than the solid nucleus of the Earth. As the water does not suffer so much attraction as the Earth, it is *left behind.* (*See Note* 30.)

"The Moon, the governess of floods."—MIDSUMMER NIGHT'S DREAM.

Q. Does the tidal wave of the ocean always rise to the SAME HEIGHT?

A. It sometimes rises *considerably higher* than it does at others.

Q. Why does the tidal wave SOMETIMES rise higher than it does at others?

A. Because *another force* sometimes *aids the Moon* in heaping up the water, but at other times *opposes* its influence.

Q. What is that OTHER FORCE that sometimes aids and sometimes opposes the Moon's attractive power?

A. The attraction of the *Sun;* for since the Sun attracts the Earth, it must also attract the superficial water of the Earth.

Properly speaking, there are two series of tidal waves travelling over the surface of the ocean; the one series lunar, the other solar; the first depending on the position of the Moon, the last on that of the Sun.

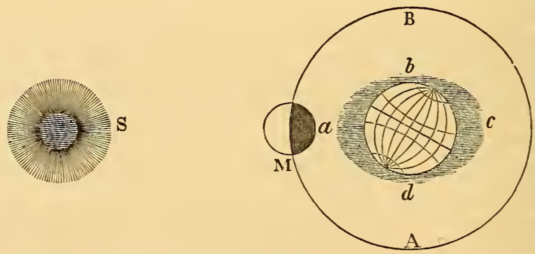
Q. Why is the Sun's attractive force LESS than that of the Moon?

A. Because the Sun is so much *farther* from the Earth than the Moon. (*See Note* 31.)

Q. How MUCH LESS influence does the Sun exert over the waters of the ocean than the Moon?

A. The Sun's influence is less than the Moon's by more than one-half. The Sun's attraction raises the level of the water of the ocean about *two* inches for every *five* inches of elevation effected by the Moon.

Fig. 84.



Let S be the Sun, and M the Moon in her orbit M A B. When the Moon is between the Earth and the Sun, as at M, the attractive force of the Sun is combined with that of the Moon to raise the waters of the Earth at *a*; and by attracting the Earth more powerfully than the waters on the opposite hemisphere at *c*, they are *left behind,* and consequently are raised above the general level; while at *b* and *d* it is low tide.

Q. When does the solar influence ADD ITS EFFECT to the lunar tidal wave, and AUGMENT its effect?

A. When the Sun is placed on the *same side* of the Earth with the Moon, and when it is placed on exactly the *opposite side* to the Moon; that is, at the periods of *new* and *full* moon.

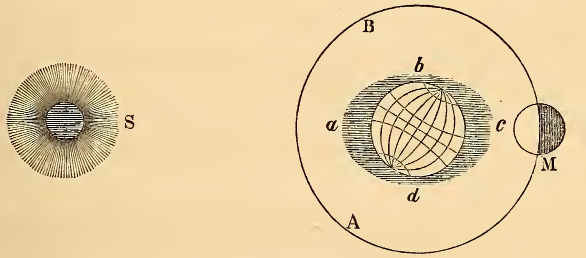
Q. Why does the solar influence add its effect to the lunar tidal wave when the Sun and Moon are both placed on the SAME SIDE of the Earth?

A. Because then the Sun and Moon both *attract* in the *same direction.* This is evidently the case at the time of new moon.

Q. Why does the solar influence also add its effect to the lunar tidal wave when the Sun and Moon are on OPPOSITE SIDES of the Earth?

A. Because then the *secondary solar wave* coincides in position with the *primary* lunar wave. This occurs at the time of full moon.

Fig. 85.



It will be seen on reference to *fig.* 85, that the attractive influence of the Moon M, is in a line with that of the Sun S, thereby creating high tides at *a* and *c*, and low tides at *b* and *d*.

Q. What are the tides called that rise the highest because the attractive influences of the Sun and Moon COMBINE to act together?

A. They are called *spring tides.*

Q. WHEN do spring tides happen?

A. Spring tides happen soon after *new and full moons.*

Q. When does the Sun attract the water of the ocean in such a way that the height of the lunar wave is REDUCED by its influence?

A. At the *first and third quarters* of the lunation.

Q. Why does the solar influence diminish the effect of the lunar influence at the first and third quarters of the lunation?

A. Because the Sun's attraction then draws the water of the ocean towards a position situated *midway between the spots* on which the crests of the two lunar waves occur.

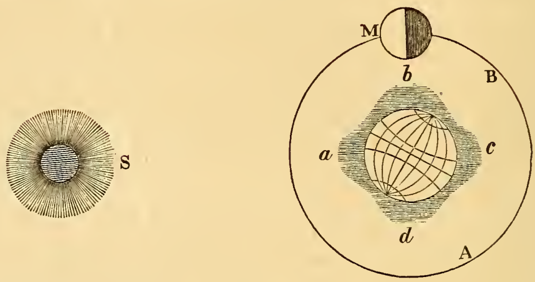
Q. What are the tidal waves of INFERIOR HEIGHT CALLED, which occur about the times of the Moon's quarters?

A. They are called *neap tides.*

Q. What is the cause of SPRING TIDES?

A. Spring tides are the result of the *addition* of the Sun's influence to the Moon's influence.

Fig. 86.



It will be seen by reference to *fig.* 86, that when the Sun and Moon are 90° apart, that is, when the Moon is in quadrature, as at M, the solar and lunar influences tend to neutralize each other. The solar waves at *a* and *c* tend to neutralize the lunar waves at *b* and *d*.

Q. What is the cause of NEAP TIDES?

A. Neap tides are the result of the *predominance* of the *Moon's influence* over the Sun's influence.

Q. What is the DIFFERENCE OF THE HEIGHT to which spring tides and neap tides rise?

A. Average spring tides rise *more than twice* as much as average neap tides.

If the influence of the Moon be represented by 5, then the influence of the Sun must be represented by 2; but as the spring tides are caused by the combined influences of the Sun and Moon, their average height may be expressed by 7, which is formed by adding 5 and 2 together; while the average height of the neap tides may be expressed by 3, which is formed by taking 2 from 5; because they are caused by the predominance of the lunar over the solar power.

Q. Do the spring tides of the ocean always rise to the SAME HEIGHT?

A. No; spring tides generally rise as much more than neap tides as 7 is greater than 3; but sometimes they rise as much more as 10 is greater than 3.

Q. What is the DIFFERENCE between the rise of the highest and the lowest tidal wave?

A. The *highest* rise of the tidal wave is rather more than *three times* the lowest rise.

Q. Why do the spring tides rise to DIFFERENT EXTENTS at different times?

A. Because the Sun and Moon are at *different distances* from the Earth at different times.

Q. Why do the Sun and Moon exert DIFFERENT INFLUENCES at different distances?

A. As the power of attraction acts with *diminishing energy* at *increasing distances*, consequently both Sun and Moon must influence the waters of the Earth less when they are *more distant* from them.

The power of the Sun varies from this cause by nearly one-tenth, and that of the Moon by nearly one-half.

Q. Does any given tidal wave rise EQUALLY throughout the WHOLE SURFACE of the ocean?

A. No; each tidal wave rises higher in that part of the ocean that is *most immediately under* the Moon and Sun. (*See Note* 32.)

Q. Are LAKES and SMALL BODIES of water subject to tides?

A. No; the disturbing action of the Sun and Moon can only become sensible on *large bodies of water.*

Q. What large bodies of water are the PRINCIPAL SOURCES of our tides?

A. The *oceans*, especially the Pacific.

The tide raised in the Pacific is transmitted to the Atlantic Ocean, and moves in a northerly direction along the coasts of Africa and Europe. It is, however, modified by the tide raised in the Atlantic. Sometimes the tides of these two great oceans are united, and at other times are in opposition to each other, so that the tides rise higher or lower in proportion to their combination or difference.

Q. Do tides rise to the SAME HEIGHT in the open sea that they do in channels?

A. They do *not.* They rise to a much *greater height* in narrow channels than in the open sea, on account of the obstructions they meet with.

At St. Malo, on the coast of France, the tides rise as high as fifty feet, because the water is more confined in the British Channel than in the wide ocean. On the shores of some of the South Sea islands, near the centre of the Pacific, the tides do not rise above one or two feet. In some parts of the Bay of Fundy the tides rise to the height of 120 feet.

Q. Have the WINDS any influence on the tides?

A. They *have;* as they *conspire with* or *oppose* the tides, they serve to raise or depress the tidal wave.

Although the wind has a powerful effect upon the *surface* of the ocean, its disturbing influence does not extend more than a hundred feet below.

Q. What is the RISING and FALLING of the tides called?

A. The rising of the water is called the *flow*, the falling, the *ebb*, of the tide.

Q. How LONG is the tide rising before it reaches its maximum?

A. About *six hours;* and after remaining a quarter of an hour stationary, it is about six hours falling.

Q. Of what USE are the tides?

A. The waters of the ocean are prevented from becoming *stagnant;* and the currents thus created equalize its temperature.

CHAPTER XI.

Eclipses.

Q. What is an ECLIPSE?

A. The interposition of *an opaque celestial body*, or *its shadow*, between another celestial body and the observer.

Q. What PRODUCES eclipses?

A. The *shadow* of an opaque body thrown on another by a luminary *much larger than either.*

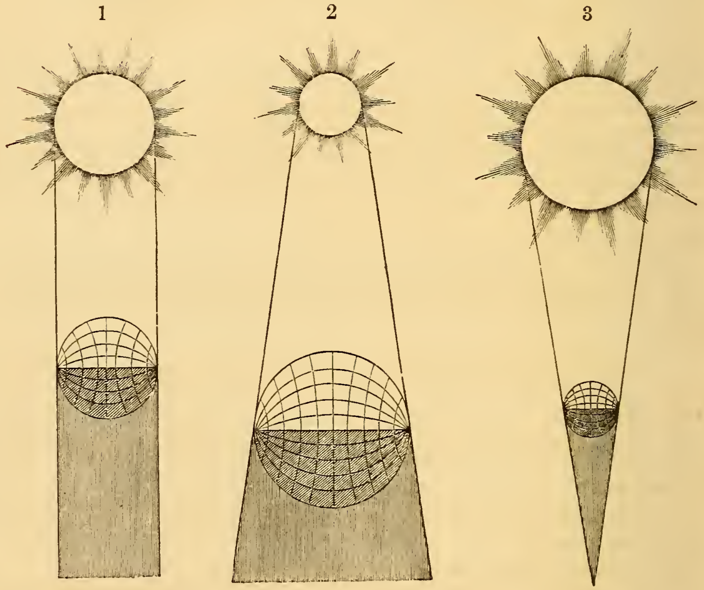
Q. What is the FORM of the shadow?

A. It is *conical.*

Q. WHY is it conical?

A. Because all the heavenly bodies known to us are *spherical*, and the shadow of a spherical body thrown by a luminary *larger than itself* must necessarily be in the form of a *cone.*

Fig. 87.



If the luminary were of the same size as the intervening body, the shadow would be as represented in *fig.* 1 of the above diagram. If, on the contrary, it were smaller than the body, the shadow would diverge, as in *fig.* 2. But the shadows are known to be conical; therefore, the luminary must be larger than the body, as shown in *fig.* 3.

Q. In what DIRECTION is the shadow of a body cast?

A. The shadow of a body always falls towards a point *directly opposite* to the luminary.

Q. What IS a shadow?

A. A *privation of light.*

Q. What is this ENTIRE PRIVATION of light, or CONICAL SHADOW, called?

A. It is called the *umbra.*

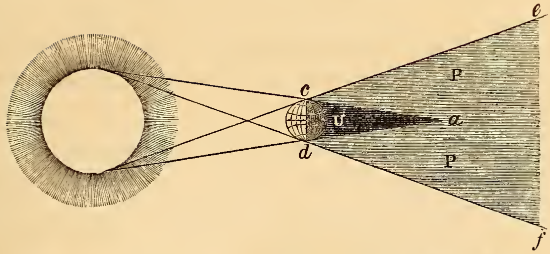
Q. Is there any OTHER KIND of shadow to be perceived in an eclipse?

A. There is a *faint* or *partial shade* observed between the perfect shadow and the full light.

Q. What is this PARTIAL SHADE called?

A. It is called the *penumbra.*

Fig. 88.



By referring to *fig.* 88, a dark conical shadow, marked U, will be seen in the direction opposite to the Sun: this is the umbra. The fainter shadow, marked P P, diverging from the Earth, is called the penumbra. They are both conical, that of the umbra having for its base the diameter of the Earth, its apex being the point *a*; the penumbra is in the form of a truncated cone *c d e f*, the base *e f* extending out into space.

Q. How MANY KINDS of eclipses are there?

A. Two; *solar* and *lunar* eclipses.

Q. WHEN do eclipses occur?

A. Eclipses can only occur when the Moon is *in* or *near her nodes.*

Q. What are the Moon's NODES?

A. Those points of her orbit which *intersect* or *cross* the orbit of the Earth.

Q. What is MEANT by the Moon being in or near her nodes?

A. She is then in or near that part of her orbit which *crosses* the *ecliptic.*

Q. Is there any heavenly body NEARER to the Earth than the Moon?

A. No; the Moon is the Earth's *nearest neighbor* in space.

Q. How does the Moon MOVE with regard to the Earth?

A. The Moon moves *round the Earth* as its immediate and constant attendant.

Q. How is it KNOWN that the Moon moves round the Earth?

A. It is seen to move around it *among the stars.* If the Moon be observed from night to night, it will be found to be constantly *leaving the stars* to the westward.

SECTION I.

Solar Eclipses.

Q. Does the Moon ever pass apparently NEAR to the Sun as she revolves round the Earth?

A. She does; and under certain circumstances she is seen to move directly *between us and the Sun.*

Q. What is a PASSAGE of the Moon between us and the Sun called?

A. It is called a *solar eclipse.*

Q. Does the Moon ALWAYS hide the Sun from sight when passing through that portion of its orbit that lies nearest to the great luminary?

A. No; it often passes through that portion of its orbit many times in succession *without* concealing the Sun.

Q. Why does NOT the Moon always conceal the Sun when moving through this portion of its orbit?

A. Because it then moves across the heavens, sometimes *above*, and sometimes *below*, the position the Sun occupies.

Q. Why does the Moon sometimes move across the heavens ABOVE the Sun's position, and sometimes BELOW it?

A. Because the orbit in which the Moon revolves is *not in the same plane* with the Earth's orbit.

Q. Is the Moon's orbit INCLINED to that of the Earth?

A. The Moon's orbit is inclined to the Earth's orbit by rather more than 5°. (*See Note* 33.)

Q. Why is it, then, that the Moon DOES sometimes pass between the Earth and the Sun?

A. The direction in which the plane of the Moon's orbit lies is *not a constant or invariable one:* it is continually changing.

Q. Does it change its inclination to the plane of the Earth's orbit?

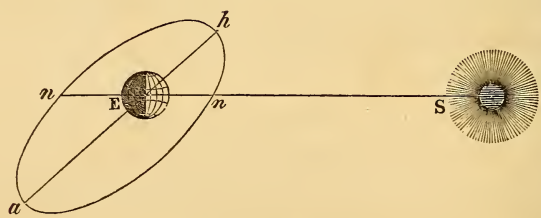
A. It *very nearly* always preserves the same inclination to the plane of the Earth's orbit while it is changing its direction.

If the pupil will drive a nail part way into the centre of a circular piece of wood or pasteboard, and then place it upon the table, so that the circular piece of wood shall rest upon its own edge and the head of the projecting nail, a slight force will make it move round, still resting partly on the head of the nail, and thus forming an inclination to the flat surface or plane of the table. As it moves, the direction in which the surface of the piece of wood lies will continually change, although the angle between it and the table will always remain the same. The plane of the Moon's orbit moves in this way; for, although continually changing, it always retains the same angle with the orbit of the Earth.

Q. What are those points of the Moon's orbit called which lie in the SAME PLANE with the Earth's orbit?

A. The points where the lunar orbit crosses the plane of the Earth's orbit are called the *nodes* of the Moon's path.

Fig. 89.



Let E S (*fig.* 89) represent the plane in which the Earth moves about the Sun, and let *n a n p* represent the Moon's orbit; then the points *n n* of the Moon's orbit, which lie in the same plane with the Earth's orbit, are the nodes, (from a Latin word signifying knots, because the terrestrial and lunar orbits are, as it were, knotted together there.) The part *p* of the Moon's orbit nearest to the Earth is called, in astronomical language,

its *perigee;* *a*, the part of the Moon's orbit farthest from the Earth, is called its *apogee;* and *a h*, the line connecting the nearest point with the farthest point, is called the line of the *apsides.*

On account of the perturbations to which the Moon's motions are subject, the form and direction of the lunar orbit are constantly changing, and fresh points of it become *nodal* in succession. Its plane rolls round as described above; and in addition to this, the line of apsides moves round in the plane of the orbit, as the two opposite spokes of a revolving wheel. The Moon revolves in the ellipse *h n a n*, it will be remembered, in a little more than 27 days. The plane of the orbit contained within the ellipse *h n a n* revolves, as the circular piece of wood is described to do, in a little more than 18 years. (*See Note* 34.)

Q. What causes a SOLAR ECLIPSE?

A. A solar eclipse is caused by the interposition of the body of the *Moon* between the *Sun* and the *Earth.*

——"As when the Sun, new risen,
Looks through the horizontal, misty air
Shorn of his beams, or from behind the Moon
In dim eclipse, disastrous twilight sheds
On half the nations, and with fear of change
Perplexes monarchs."—PARADISE LOST.

Q. When can a SOLAR ECLIPSE take place?

A. A solar eclipse can only take place when one of the *nodes* of the Moon's orbit is *nearly in a line* between the Earth and the Sun at the time of new moon.

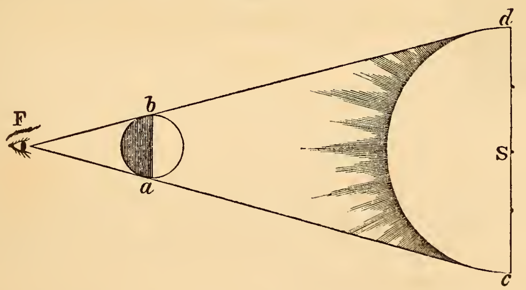
Q. Is not the Moon of SMALLER SIZE than the Sun?

A. Yes; the Moon's sphere is *four hundred times less in diameter* than that of the Sun.

Q. How is it, then, that the large Sun can be HIDDEN BEHIND the small Moon?

A. Although the Moon is 400 times *smaller* than the Sun, it is also 400 times *nearer* to us.

Fig. 90.

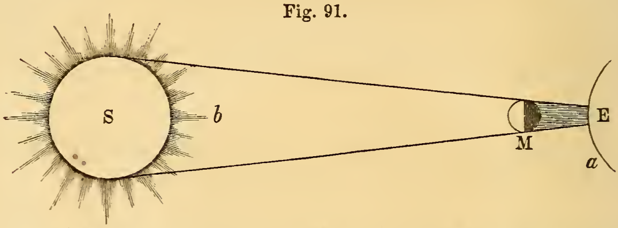


As the Sun is 400 times larger than the Moon, and also 400 times more distant, it of necessity appears to be of the same size. The line *d c*, in *fig.* 90, is four times longer than *a b*; but it is also four times more distant from F, supposed to be an observer's eye; consequently it has the same angular measurement, and seems to be of the same size. What is true of four times must also be true of 400 times, if both distance and size are increased in the same proportion.

Q. Is the ENTIRE DISC of the Sun hidden whenever the Moon intervenes between it and the Earth?

A. The entire face of the Sun is hidden only when the *centres* of the Moon and Sun fall in a straight line with the observer's eye.

Fig. 91.



If E (*fig.* 91) were an observer's eye, and M the Moon's position, no part of the Sun's face could be seen; but if the observer's eye were at *a*, (out of the line connecting the centres of the Sun and Moon,) then all that part of the Sun's disc below *b* would be visible, and all that part above *b* would be concealed.

Q. How many KINDS of solar eclipses are there?

A. Three: *partial*, *total*, and *annular*.

An eclipse is said to be central when the centres of the Sun, Moon, and Earth are in one line. This is always the case in total and annular eclipses.

Q. What is a PARTIAL eclipse of the Sun?

A. An eclipse is said to be *partial* when only a *portion* of the eclipsed orb is hidden from view.

In *fig.* 91 the observer at *a* would see a partial eclipse.

Fig. 92.

Fig. 92 represents a partial eclipse, in which only nine digits of the Sun are obscured.

Q. When an eclipse is only partial, how can its EXTENT be recorded?

A. The disc of the Sun is supposed to be divided into *twelve equal parts*, called *digits;* and the number of the parts eclipsed is recorded as so many digits.

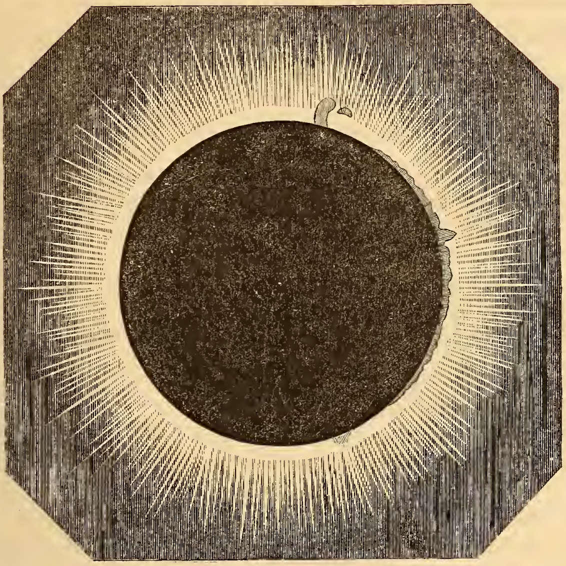
Q. What is a TOTAL eclipse?

A. An eclipse is total when the *whole body* is obscured.

Q. What appearance is presented to the eye during a TOTAL SOLAR eclipse?

A. A *round*, *black centre*, sometimes surrounded by a halo of faint light, appears in the place of the Sun.

Fig. 93.



The appearance of a total eclipse of the Sun is shown in *fig.* 93.

Q. What is the halo of faint light CALLED ?

A. The halo of faint light which surrounds the dark body of the Moon is called the *corona.*

Q. What CAUSES the corona ?

A. Astronomers are undecided as to the cause of the corona.

Some suppose it to be portions of the solar atmosphere, or of the solar beams, bent by the influence of the Earth's atmosphere; others suppose it to be the atmosphere of the Moon, which, though extremely rare, becomes visible during an eclipse of the Sun. But there seems to be objections to both these conjectures.

Q. How LONG can a total eclipse continue ?

A. A total solar eclipse, at any spot on the terrestrial globe, cannot last longer than *from three to four minutes.*

Q. What is the PHENOMENON attendant on a total eclipse ?

A. During a total solar eclipse, a deep and *gloomy twilight* takes the place of daylight, and the *brighter stars appear.*

"'Tis but the daylight sick;
It looks a little paler; 'tis a day
Such as a day is, when the Sun is hid."—MERCHANT OF VENICE.

Q. Is the Sun eclipsed over a LARGE PORTION of the Earth's surface at once ?

A. No; the Moon's shadow is always *small* where it touches the Earth's surface.

The greatest diameter of the Moon's shadow, where it touches the Earth, is only about one hundred and seventy-five miles; consequently, those inhabitants of the Earth who

are beyond this circle of one hundred and seventy-five miles of shadow see the Sun shining as usual.

The phenomenon of a solar eclipse may be compared to that produced by a small cloud passing between us and the Sun. The cloud casts a shadow on the Earth as it moves along, and to those observers on whom the shadow falls, the Sun is for a time obscured, while those beyond the shadow enjoy the sunshine. Just so does the Moon's shadow fall on the Earth, and for a time obscures the Sun, while beyond its limits the inhabitants see him as usual.

Q. Why is the Moon's shadow so SMALL when it comes in contact with the Earth?

A. Because the body of the Moon being so much *smaller* than that of the Sun, it just hides the Sun to an observer on the Earth; therefore, the Moon's shadow must end in a *point* near the Earth's surface.

Q. When a large luminous body shines on a small opaque one, what kind of a shadow is cast?

A. The shadow must be a *diminishing one*, in the form of a *cone.*

During a solar eclipse a small circle of darkness, formed by the point of the lunar shadow, creeps along over the surface of the Earth.

Q. What is an ANNULAR eclipse?

A. An annular eclipse of the Sun is a total obscuration of the *centre* of that luminary, leaving only a *bright ring* of his disc visible.

Q. When does an annular eclipse of the Sun OCCUR?

A. An *annular eclipse* of the Sun occurs when the Earth is in *perihelion*, or in that part of her orbit *nearest* to the Sun, and when the Moon is in *apogee*, or in that part of her orbit *farthest* from the Earth.

Q. Cannot a TOTAL eclipse occur when the Earth is in PERIHELION and the Moon in APOGEE?

A. No; when the Earth is in her perihelion, the Sun's disc appears of its greatest magnitude; and when the Moon is in apogee, her disc appears of its least magnitude; in that case the Sun's disc appears larger than the Moon's; therefore, a total eclipse cannot occur.

The reason why the Sun appears of its greatest magnitude when the Earth is in perihelion, is, that the nearer a body is to us, the larger it appears; thus, the Sun appears of its greatest size when the Earth is in perihelion, or in that part of her orbit nearest to the Sun. And as the Moon is at her greatest distance from the Earth at her apogee, she consequently appears smaller than when at her perigee, or that point of her orbit nearest to the Earth.

Q. If the eclipse cannot be total, WHAT KIND of eclipse will take place?

A. An *annular eclipse.*

Q. What is the APPEARANCE produced by an annular eclipse?

A. The body of the Moon is seen to cover the centre of the Sun, leaving a luminous *annulus* or *ring* round its edge.

Q. Does the POINT of the Moon's SHADOW fall on the Earth at the time of an annular eclipse?

A. No; when an annular eclipse occurs, the point of the Moon's shadow *falls a little short* of the Earth's surface.

Fig. 94.

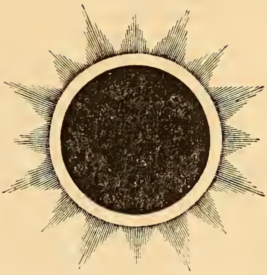


Fig. 94 represents the Sun during an annular eclipse. Although eclipses of the Moon occur more frequently to the inhabitants of *any one place,* for instance, at Philadelphia, than eclipses of the Sun, yet as the Moon's shadow covers so small a part of the Earth's surface, the eclipses of the Sun can only be visible within a circle comparatively small. But eclipses of the Moon are visible over a very large part of the Earth's surface, which is the reason why eclipses of the Moon are seen more frequently by a stationary observer than those of the Sun.

Q. How MANY solar eclipses can there be in one year?

A. There are generally about four eclipses in a year—two of the Sun, and two of the Moon; there *may be* as many as seven, but there *must be* two. When there are only two, they will both be solar, for eclipses of the Sun are more frequent than those of the Moon.

Q. When can there NOT be any eclipse of the Sun?

A. When the Moon is so situated that at the time of new moon she is *more than seventeen degrees* from her *node,* no eclipse of the Sun can happen.

Q. What is this distance of seventeen degrees CALLED?

A. It is called the *solar ecliptic limit;* that is, it is the *farthest possible* distance from the node at which an eclipse of the Sun *can* take place.

SECTION II.

Lunar Eclipses.

Q. Has not the EARTH a SHADOW behind it as well as the Moon?

A. Yes; the Earth's sphere is *opaque* as well as the Moon's sphere, and must also cast a shadow behind it.

Q. What is the FORM of the Earth's shadow?

A. The Earth's shadow, like the Moon's, is of a *conical form.*

Q. Why is the Earth's shadow CONICAL?

A. Because the Sun is so much *larger* than the Earth; and when a large luminous sphere illuminates a smaller one, the shadow *must be conical.*

Q. Is the Earth's conical shadow LONGER than the Moon's?

A. The Earth's shadow is nearly *four times longer* than the Moon's shadow.

Q. Why is the Earth's shadow nearly FOUR TIMES LONGER than the Moon's shadow?

A. Because the diameter of the Earth's sphere is nearly *four times greater* than the diameter of the Moon.

The Moon's shadow extends about two hundred and forty-thousand miles from the lunar sphere, and the Earth's shadow extends about eight hundred thousand miles from the terrestrial sphere.

Q. Does the Earth's shadow extend, then, BEYOND the orbit of the Moon?

A. Yes. The Earth's shadow is *nearly four times longer* than the distance of the orbit of the Moon from us.

Q. Does the Moon sometimes PASS INTO the Earth's shadow?

A. As the Sun and Moon are sometimes situated in *one straight line* with regard to an observer on the Earth, therefore the Moon must occasionally be immersed in the Earth's shadow.

Although the cone of the Earth's shadow is eight hundred thousand miles in length, there is no planet or satellite of the solar system (except our Moon) which is sufficiently near to be obscured by it. Consequently, our Earth cannot eclipse any of the other planets.

Q. What HAPPENS when the Moon is in the Earth's SHADOW

A. The Moon is no longer illuminated by the light of the Sun, and is then said to be *eclipsed.*

Q. How is the SUN HIDDEN in the solar eclipse?

A. By the dark body of the Moon coming in *front of it.*

Q. How is the MOON HIDDEN in a lunar eclipse?

A. In the lunar eclipse the Moon is hidden by coming into the *dark shadow* of the Earth.

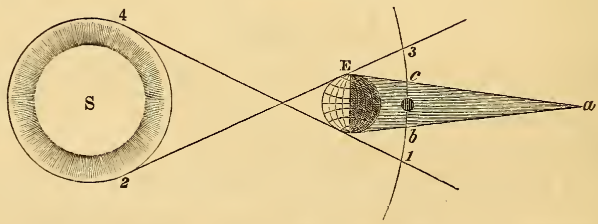
Q. At what PERIOD of the Moon's age does a lunar eclipse occur?

A. A lunar eclipse can only occur at the period of *full moon.*

Q. What is the BREADTH of the Earth's shadow when the Moon traverses it?

A. The shadow of the Earth at the distance of the orbit of the Moon, (two hundred and forty thousand miles,) is between *five and six thousand miles broad.*

Fig. 95.



A cone that is eight thousand miles across at its base, and eight hundred thousand miles from base to apex, would measure between five and six thousand miles in breadth at the distance of two hundred and forty thousand miles from the base. Let S (*fig.* 95) be the Sun, and E the Earth; then the length of the Earth's shadow, measured from E to *a*, is eight hundred thousand miles; and the breadth of the shadow from *b* to *c*, where the Moon traverses it, is about five thousand six hundred miles.

Q. How LONG does it take the Moon to TRAVEL through the Earth's shadow?

A. The Moon cannot be totally eclipsed more than *an hour and three-quarters.*

A lunar eclipse may continue for five hours and a half, from the Moon's first entrance into the Earth's penumbra until her emersion from it.

Q. Is the Earth's shadow bounded by an even, SHARP OUTLINE, when seen over the disc of the moon?

A. No; the edge of the Earth's shadow is so gradually *softened off*, that no precise line can be marked as its limits.

It is not possible to discern where the edge of the shadow really begins. More and more of the Sun's disc is concealed from the Moon in succession, so that the solar light is gradually and progressively, instead of suddenly, withdrawn from it. For instance, when the Moon is at 1 in her orbit 1 *b c* 3, (*fig.* 95,) it receives the solar rays that issue from 2, but not those that issue from 4; and when at 3, it receives those from 4, but not those from 2. Consequently, while passing from 1 to *b* and from *c* to 3, it is in regions of diminished light, but not in entire darkness; during this time its disc appears dimmed, but not obscured.

Q. What is the IMPERFECT SHADOW called which borders the true shadow of the Earth?

A. The imperfect shadow which borders the true shadow of the Earth is called the *penumbra,* which means *almost shadow.*

Q. What is the meaning of UMBRA?

A. Umbra means *shadow.*

Q. Are eclipses of the Moon as FREQUENT as those of the Sun?

A. No; lunar eclipses are *not as frequent* as solar eclipses.

Q. Are MORE SOLAR eclipses than lunar eclipses seen from any one point of observation on the Earth's surface?

A. No; *lunar eclipses* are more frequently seen than solar eclipses from any one point of observation.

Q. As there are FEWER lunar eclipses than solar eclipses, how can this be accounted for?

A. A solar eclipse is only visible over a *small portion* of the Earth's surface, but a lunar eclipse is commonly visible to a very *large portion* of it. Consequently, any stationary observer more frequently sees lunar than solar eclipses.

Q. Does the Moon sometimes undergo PARTIAL ECLIPSE like the Sun?

A. Yes; it frequently happens that the body of the Moon passes the *edge of the Earth's shadow* in such a way that a part of her disc is in the shadow and the other part outside of it.

Q. Is the Moon's surface QUITE HIDDEN from human vision when under total eclipse?

A. It rarely becomes *invisible*, but may be faintly seen, of the color of tarnished copper.

This reddish appearance is owing to the refraction of the Sun's rays in passing through our atmosphere.

Q. Is it more easy to CALCULATE BEFOREHAND the time of a solar, or lunar eclipse?

A. It is more easy to calculate beforehand the time at which a *lunar eclipse* will occur.

Q. Why is it MORE EASY to calculate the time of a lunar eclipse?

A. Because the time of the beginning and ending of a lunar eclipse, and also the time of its continuance, are quite independent of the *observer's position* on the Earth's surface.

Q. Is the observer's position IMPORTANT in the calculation of a solar eclipse?

A. In a solar eclipse the observer's position is an *important element* in the calculation.

Q. Why are astronomers more generally interested in watching SOLAR than LUNAR ECLIPSES?

A. Because the time of the beginning and ending of a solar eclipse can be more *accurately noted* than in the lunar; and when the solar eclipse is total, it is accompanied with the *sudden withdrawal* of the solar influence from the Earth.

Q. Can any kind of REGULARITY be discovered in the RECURRENCE of eclipses?

A. Yes; after an interval of *eighteen years and two hundred and sixteen days*, the same eclipses occur over again.

More properly, the same eclipses occur again after a period of 6585 days. It is supposed that a knowledge of this fact may have enabled the ancient astronomers to foretell eclipses. This cycle, or period of 18 years, was termed *saros* by the Chaldeans.

On the first day of March, 1504, a lunar eclipse occurred, a foreknowledge of which enabled Christopher Columbus to obtain supplies for his crew, who were in a suffering condition. He was at that time at the island of Jamaica; and after using all the means in his power to obtain relief from the natives without success, he threatened them with the displeasure of the Great Spirit, which he said would be manifested on that very evening by the privation of the Moon's light. At first they disregarded his threat, but when the eclipse commenced, they loaded him with gifts, beseeching him to withdraw the calamity, and promising to befriend him ever after.

SECTION III.

Transits.

Q. What is the meaning of TRANSIT?

A. Transit means the *change of place* or *passage* of a planet over the disc of the Sun.

This term is applied to the passage of the Sun over the meridian of a place, and also to the passage of a heavenly body across the field of view of a telescope.

Q. Do ALL the planets transit the Sun's disc?

A. To the inhabitants of the Earth the *interior planets* only appear to transit the Sun.

Q. Why do the planets MERCURY and VENUS ONLY appear to transit the Sun's disc?

A. Because the orbits of those planets are *within* the orbit of our Earth.

Q. Under what CONDITIONS do transits occur?

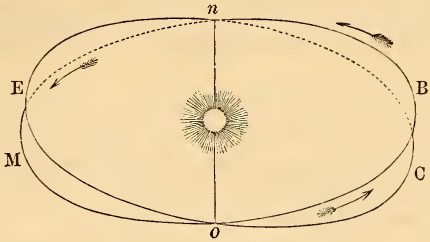
A. A transit can only occur when the planet Mercury or Venus is very near its node.

The node, it will be remembered, is that point of a planet's orbit which intersects the plane of the Earth's orbit. Were the orbits of Mercury and Venus in the same plane with the orbit of the Earth, they would transit the Sun's disc at every revolution. It is only when the planet is in, or very near, the plane of the ecliptic, that a transit can occur.

Let *n o* be the points in which the orbit M *o* B *n* of a planet intersects the plane of the ecliptic E *o* C *n*; the part *o* B *n* lies *above* the plane of the ecliptic, and the other half, *n* M *o*, *below* it. That point through which the planet passes in ascending above the plane of the ecliptic is called the ascending node, which in the figure is the point *o*;

the point *n* denotes the descending node, or point where the planet descends below the plane of the ecliptic, as it moves in the direction of the arrows.

Fig. 96.



Q. What is the APPEARANCE produced by a transit?

A. The body of the planet is seen to *cross* the Sun's disc like a *dark spot.*

Q. What do transits serve to PROVE?

A. They prove that the planet is an *opaque* body, shining only by reflected light.

Q. What TERMS do astronomers use to denote the ingress and egress of the opposite limbs of the planet?

A. *Internal* and *external contact.*

Q. What is the meaning of INTERNAL CONTACT?

A. The *moment* of the *perfect projection* of the planet on the *disc* of the Sun, before the appearance of a luminous line between the edge of the planet and the limb of the Sun. This is the *first* internal contact. The *last* internal contact is when the planet, having passed over the Sun's disc, has not yet protruded beyond his limb.

Q. What is meant by EXTERNAL CONTACT?

A. The moment the planet *touches* the Sun's limb, before any apparent *indentation* is perceptible. This is the *first* external contact. The *last* external contact is when the planet, having passed over the Sun's disc, its edge is still in contact with the Sun's limb.

Place a silver dollar on the table, and a small gold one by its side. Draw the gold dollar towards the silver dollar, so that their edges may just touch. This is the *first external contact.* Now, continue to move the gold dollar over the silver one: the moment the whole of the gold dollar is on the silver one, with their edges still together, is the time of the *first internal contact.* Continue to draw the gold dollar over the silver one, till their opposite edges meet: this is the point of the *last internal contact.* Continue the motion, and the edge of the gold dollar will protrude over the edge of the silver dollar, and finally will leave it entirely. The moment when the gold dollar is entirely off from the silver dollar, but their edges are yet together, is the moment of the *last external contact.*

Q. Do transits occur at EVERY REVOLUTION of the planet?

A. They do not; because the orbits of the planets Mercury and Venus are *not in the same plane* with the orbit of the Earth.

DIVISION I.—TRANSITS OF MERCURY.

Q. In WHAT PART of the Earth's orbit are the nodes of Mercury's orbit?

A. In that part of the Earth's orbit through which she passes in the months of May and November; that is, in the signs *Taurus* and *Scorpio.*

Q. How OFTEN do transits of Mercury occur?

A. They usually occur at intervals of *thirteen* and *seven* years.

Those transits at the ascending node occur in November; those at the descending node, in May. The intervals, considering each node separately, occur usually in the order of 13, 13, 13, 7, &c.; and after a period of two hundred and seventeen years, the transits occur in regular order again.

Q. How long since the FIRST TRANSIT of Mercury was observed?

A. The first recorded transit of Mercury occurred on the 7th of November, 1631.

Q. WHO observed this transit?

A. An astronomer in Paris, by the name of *Gassendi.*

Kepler, one of the greatest astronomers of that day, calculated the time this transit would occur, and notified astronomers to that effect. His calculations were proved correct by the observations of Gassendi, who first thought the planet was a spot on the Sun; but soon found by its motion that it was the body of the planet Mercury projected on the Sun's disc.

Q. Are the transits of Mercury IMPORTANT to astronomers?

A. Yes; but they are of less importance than the *transits of Venus.*

Q. Why are they LESS important than the transits of Venus?

A. Because, as the planet Mercury is so near the Sun, it is more difficult to ascertain the Sun's *parallax* by means of the transit of that planet across his disc.

Q. What is meant by HORIZONTAL PARALLAX?

A. It is the *angle* subtended by the *semi-diameter of the Earth,* if viewed from the Sun, Moon, or a planet.

Q. Of what USE is the determining of the Sun's parallax?

A. It affords the means of ascertaining the *distance of the Earth from the Sun.* (*See Note* 35.)

Parallax is explained in Part iii. chap. i. sec. i. div. vi.

DIVISION II.—TRANSITS OF VENUS.

Q. Do transits of Venus occur as FREQUENTLY as those of Mercury?

A. No; they recur at intervals of *eight* and *one hundred and thirteen years;* but these intervals are by no means regular.

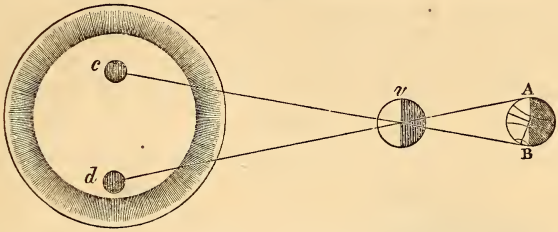
Q. Are transits of Venus of any IMPORTANCE to astronomy?

A. Transits of Venus are of great importance, enabling astronomers to determine *the distance of the Earth from the Sun* with greater accuracy than any other known method.

Q. How can the Sun's distance from the Earth be DISCOVERED by a transit of Venus?

A. The dark body of the planet appears to cross a *different portion* of the Sun's disc, as it is observed from one or the other of two *widely-separated* stations on the Earth's surface.

Fig. 97.



Let A B (*fig.* 97) represent the Earth, and *v* the planet Venus. If two spectators be placed on opposite extremities of the Earth's surface, one at A, and the other at B, when the observer at A sees the centre of the planet projected on the Sun's disc at *d*, at the same moment will the observer at B see it at *c* on the face of the Sun. Now, if these two observers mark the precise moment of ingress or egress of the planet, the angular measure of the distance *c d* can easily be ascertained by calculation.

Q. Why is the transit of Venus viewed from two WIDELY-SEPARATED stations?

A. Its *path* on the Sun's disc is *noted by each observer;* and from the amount of the *displacement* observed, owing to the effect of parallax, the relative distances of Venus and the Sun can be ascertained.

The parallax of a celestial body is the angle under which the radius of the Earth would be seen, if viewed from the centre of that body.

Q. Do transits of Venus happen EVERY TIME the planet passes through that portion of its orbit nearest to the Earth?

A. They do not; because the plane of the planet's orbit is not in the same plane as the orbit of the Earth.

Owing to the inclination of the orbit of Venus to the plane of the ecliptic, she is sometimes above, and sometimes below, the Sun's apparent place.

Q. Have transits of Venus been often observed by astronomers?

A. No; the first recorded transit of Venus is that which occurred in the year 1639.

This transit, supposed to be the first witnessed by any human being, was observed by a young man named Jeremiah Horrox, of Hoole, near Liverpool. He found the tables which Kepler constructed from the observations of Tycho Brahé were incorrect, inasmuch as they indicated a transit in the year 1631; but as none appeared, he applied himself to discover the error, and succeeded so far as to predict a transit in 1639, which actually took place. He was very anxious to witness this rare phenomenon, and for this purpose commenced his observations at a very early hour on the day of the expected event. But as this was Sunday, he did not permit his desire to witness this rare phenomenon to interfere with his scrupulous observance of the day, believing it to be his duty to attend divine service twice. He was, however, in the interval, favored with the sight he had so long anticipated, and for which he had labored for eight years.

Q. Have the transits of Venus been of interest to ASTRONOMERS ONLY?

A. No; the transit of 1769 was considered of so much im-

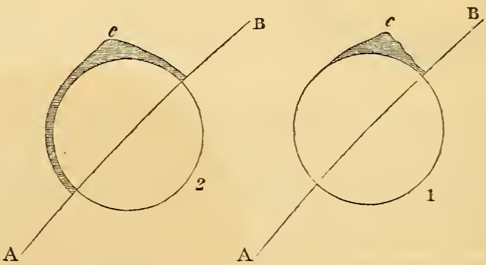
portance, that the *British Government* equipped an expedition on a large scale, and sent able persons to the Sandwich Islands to observe it.

The expedition, under the command of Captain Cook, was sent out to the island of Tahiti, by the British Government, to observe this transit. Other European powers made liberal preparations, and sent out astronomers to various parts of the world.

Q. Were any PECULIARITIES observed during that transit of Venus?

A. Yes; a *pyramid of light* was observed on that side of the planet which was not yet in contact with the Sun, which increased until one-half the disc of Venus was projected on the solar disc.

Fig. 98.



The above figures represent the form of this light at its first appearance, and after the centre of the planet had arrived at the edge of the Sun's disc. The drawing is from that made by Mr. David Rittenhouse, who observed this transit at his observatory at Norristown, near Philadelphia.

A B (*fig.* 98) represents a portion of the orbit of Venus, and *c* (*fig.* 1 of the same diagram) gives the form of the first appearance of the pyramidal light. *Fig.* 2 shows the light as it appeared when the centre of Venus was in a line with the outer edge of the Sun's disc. It will be seen that it is then extended half round the orb of the planet. (*See Note* 36.)

SECTION IV.

Occultations.

Q. What is an OCCULTATION?

A. An occultation is the *concealment* of a *planet* or *fixed star* by another planet or the Moon.

Q. To what is this CONCEALMENT of a planet or star owing?

A. The Moon passes *between* the Earth and the planets and stars, and *hides* them from our view; for the Moon is much nearer to us than any other celestial body.

Q. Does the Moon occult or conceal the MORE DISTANT heavenly bodies as it passes between us and them?

A. Yes; the Moon *conceals* planets or stars which lie directly in its path.

Q. What is a STAR'S OBSCURATION by the Moon's opaque body called?

A. The obscuration of a star by the Moon is called an *occultation* of that star.

Q. Does the occultation of a star occur GRADUALLY, or INSTANTANEOUSLY?

A. Planets are obscured by *slow degrees;* but fixed stars disappear *instantaneously.*

Q. Why are PLANETS concealed by slow degrees?

A. Planets have *perceptible dimensions,* and therefore the Moon's edge must require some time to pass over them; but the fixed stars are *without measurable discs,* for being at such immense distances they appear as bright points, consequently the Moon conceals them entirely the very moment its edge appears in contact with them.

"See;
The Moon is up, it is the dawn of night;
Stands by her side one bold, bright, steady star."—BAILEY.

Fig. 99.

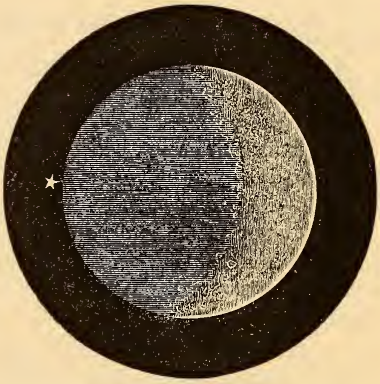


Fig. 99 represents the new Moon immediately before the occultation of a star. The star is about to disappear behind the unilluminated portion of the lunar disc.

Q. What occurs when the occultation of a star happens BEFORE the period of full moon?

A. When the occultation occurs before the time of full moon, the star *suddenly* disappears behind the dark limb of the Moon, the unilluminated portion of the Moon being then towards the *east.*

Q. What happens when the occultation occurs AFTER the period of full moon?

A. After the period of full moon the occulted star *reappears* from behind the dark limb in the same sudden manner, the *unilluminated* portion of the Moon then being turned towards the *west.*

CHAPTER XII.

Comets.

"Stranger of Heaven, I bid thee hail!
  Shred from the pall of glory riven,
That flashest in celestial gale—
  Broad pennon of the King of Heaven.
Whate'er portends thy front of fire,
  And streaming locks so lovely pale
Or peace to man, or judgments dire,
  Stranger of Heaven, I bid thee hail!"—ETTRICK SHEPHERD.

Q. Are the Moon and planets the only bodies seen to WANDER ABOUT in the nocturnal sky?

A. There are yet *other bodies* which are occasionally seen to move among the stars.

Q. What are those, NOT PLANETARY, yet WANDERING, bodies called?

A. They are called *comets.* The word comet is derived from a Greek word, signifying *hair.*

Q. Is every part of a comet EQUALLY BRIGHT?

A. No; the *central point* is generally the brightest; this is called the *nucleus* or *head*, which is sometimes surrounded by a nebulous covering called the *envelope* or *coma;* the luminous train by which most comets are accompanied is called the *tail.*

The tail, however, is by no means an invariable appendage to comets.

Q. How are comets DISTINGUISHED from planets?

A. Comets present themselves with discs of *cloudy light*, and planets have *well-defined* discs.

Xenocrates termed comets "clouds of light."

Q. Are the motions of the comets directed AROUND THE SUN, as those of the planets are?

A. Yes; the comets are supposed to move round the Sun in *elliptical orbits*, but of such great eccentricity that *some* are considered by astronomers to be of *infinite length.*

Q. What, then, is the NATURE of a comet's path through space?

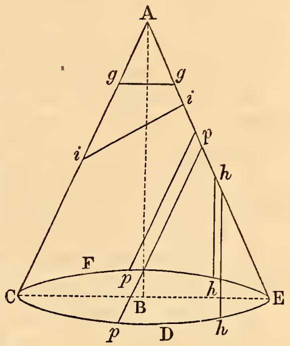
A. The orbits of comets have mostly the form of *very elongated ellipses.*

In the ages of superstition, comets were regarded as omens of some coming evil; and more than once have influenced the progress of sublunary affairs.

"At His command, affrighting human kind,
Comets drag on their blazing length behind;
Nor, as was thought, do they at random rove,
But in determined times, through long ELLIPSES move"

If a cone be cut in different directions, it may be made to form *five* different figures, known as the *Conic Sections.* Thus, in *fig.* 100, A is the apex of the cone, the dotted line A B the axis, and C D E F the base. As the axis is perpendicular to the base, the figure is a right cone. If a right cone, having a circular base, be cut through the axis from the apex to the base, the section will be a triangle; if cut through both sides by a plane parallel to the base, as *g g,* the section is a circle; if the cone be cut slanting through both sides, the section will be an ellipsis, as *i i;* if cut by a plane parallel to one of its sides, as *p p,* the section will be a parabola; and if cut by a plane parallel to the axis, it will be a hyperbola, as *h h.*

Fig. 100.



Q. Where is the Sun SITUATED in a comet's orbit?

A. The Sun is situated in one of the *foci* of the orbit.

Q. Do comets that move in elliptical orbits ever return INTO SIGHT AGAIN after they have once disappeared?

A. All comets that move in ellipses *must* reappear after a certain length of time; provided, that in the mean time no accidental disturbance influences their motions. But those comets which move in *hyperbolic* orbits can never visit our system *more than once.* (*See Note* 37.)

Q. Are any comets known thus to reappear PERIODICALLY?

A. Yes; *several comets* are now known to return into sight at regular and ascertained periods.

Q. Do comets on their return always present the SAME APPEARANCE?

A. No; comets are *liable to change their appearance,* so as not to be recognised again.

Q. How can it be DEFINITELY KNOWN that comets ever return to our system?

A. A comet is only known to be the *same body,* on its return to our system, when the *elements* of its orbit are the same as those observed to belong to a comet which has appeared before.

Q. What are the ELEMENTS of an orbit?

A. Certain *fixed quantities* and *facts* are called *elements,* which are necessary in order to determine the form and extent of an orbit.

Q. What ELEMENTS are necessary to be identical in order to determine whether a comet has ever been observed before?

A. *Five* elements are required to be identical to prove the recurrence of a comet; namely—

1. The *perihelion distance;*
2. The *longitude of the perihelion;*
3. The *longitude of the node;*
4. The *inclination of the orbit;* and
5. The *time of perihelion passage.*

Q. What is the PERIHELION DISTANCE?

A. It is the *distance* of the perihelion point from the *Sun*, which is the *nearest approach* of the comet to that luminary.

Q. What is meant by the LONGITUDE of the perihelion?

A. The longitude of a planet or comet at the time of its *least distance* from the *Sun*, as viewed from the Sun's centre.

Q. What is the longitude of the ascending NODE?

A. The longitude of the planet or comet as seen from the Sun when *it is in its ascending node.*

Q. What is the INCLINATION of the orbit?

A. The *angle* formed by the plane of the ecliptic with the plane of the orbit of the planet or comet.

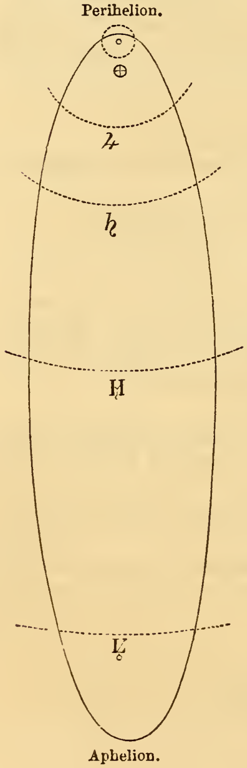
Q. What is to be understood by the TIME of PERIHELION PASSAGE?

A. The *moment* when a comet arrives at its *least distance* from the Sun.

Astronomers usually adopt a fixed meridian of their own country in expressing the epoch of arrival at perihelion.

Fig. 101.

Perihelion.



Aphelion.

Q. Do any of these comets keep WITHIN the limits of our system?

A. Yes; some of these comets revolve in orbits contained within the orbit of the *planet Neptune.*

Q. By what NAME are these comets distinguished?

A. The are known as "*the comets of short period.*"

Their names and periods are as follows:

Encke's,	completing its	revolution in	3	years	108	days.
De Vico's,	"	"	5	"	271	"
Brorsen's,	"	"	5	"	214	"
D'Arrest's,	"	"	6	"	163	"
Biela's,	"	"	6	"	227	"
Faye's,	"	"	7	"	163	"

Besides these, several other comets are known to have short periods.

The orbits in which these *comets of short period* move lie in planes not very much inclined to the Earth's orbit. Brorsen's comet has an inclination of 31°, which is 3° less than the inclination of the orbit of the planet Pallas. They all move in their orbits in the same direction with the planets.

Fig. 101 represents the orbit of a comet whose period of revolution is 75 years. It will be seen that it extends beyond the orbit of Neptune.

"Lo! from the dread immensity of space,
Returning with accelerated course,
The rushing comet to the Sun descends;
And as he sinks below the shading Earth,
With awful train projected o'er the heavens,
The guilty nations tremble."—THOMSON.

Q. Are ALL comets believed to move in elliptical orbits?

A. It is well known that *some* comets do *not* move in ellipses. They are known to have *hyperbolic* paths.

Q. Do the comets which move in hyperbolic paths EVER RETURN into sight when they have once left the Sun?

A. They do *not.* They visit the Sun *once*, and then sweep off into space, to return no more.

——"Where the TRAIN
Of comets wander in eccentric ways,
With infinite excursion through th' immense
Of ether, traversing from sky to sky
Ten thousand regions in their winding road,
Whose length to trace imagination fails"

Q. Have MANY comets been seen at different times in the heavens?

A. Yes; *several hundred* comets have been seen at different times.

Lalande enumerates no less than seven hundred. Arago believes that there cannot be less than *seven millions* of comets passing within the influence of our planetary system. Kepler used to speak of the comets being as numerous as fishes in the sea.

The following table, exhibiting the number of fully authenticated comets in each century, is from the recent work of Mr. J. R. Hind:

Century.	Observed in Europe and China.	Century.	Observed in Europe and China.
I.	22	XI.	36
II.	23	XII.	26
III.	44	XIII.	26
IV.	27	XIV.	29
V.	16	XV.	27
VI.	25	XVI.	31
VII.	22	XVII.	25
VIII.	16	XVIII.	64
IX.	42	XIX. (first half)	80
X.	26		

Giving a total of 607.

Q. Does every comet show itself with sufficient brilliancy to be perceptible to the NAKED EYE?

A. A very *small proportion* of comets are ever visible to the naked eye. (*See Note* 38.)

Immense numbers must approach near to, and recede from the Sun unknown to us, owing to the heavens being obscured by clouds and fogs; besides, many traverse that part of the heavens above the horizon in the daytime, which would render them invisible to us. This has been proved; for according to Seneca, during a total eclipse of the Sun which happened B. C. 62, a large comet was seen in close approximation to that luminary. Many comets have appeared which were visible by the naked eye in the daytime; namely, those which appeared B. C. 43, A. D. 1402, 1472, 1532, 1744, and 1843. A comet mentioned by Diodorus Siculus was so brilliant as to cast shadows during the night as strongly marked as those formed by the Moon.

Q. Do all comets move in the SAME DIRECTION?

A. No. Comets move in *all possible directions:* some from west to east, like the planetary bodies; others from east to west.

Q. Are the paths of the comets, like the planets, confined to the zone of the ZODIAC?

A. No; all except the *comets of short period* make their fitful appearances indifferently in all the regions of the visible heavens.

Q. What FORM do comets most commonly assume?

A. When they are first seen, comets mostly appear as spherical or elliptical portions of light.

Q. Is the aspect of each comet FIXED and IMMUTABLE like that of each individual planet?

A. No: the form and aspect of each separate comet undergoes *continual change* so long as it remains visible.

Q. Is the visible surface of comets EQUALLY BRILLIANT in every part?

A. Most comets have comparatively bright centres, surrounded by an envelope having a cloudy or *hairy* appearance.

Q. What is the BRIGHTER CENTRE of a comet called?

A. The brighter centre is called the comet's *nucleus.*

Q. When comets first make their appearance, are they BRIGHT?

A. Comets generally come into sight as *small specks* of light, which are barely visible with good telescopes. As they advance nearer the Sun, these specks become *larger* and *brighter.*

Q. Of what kind of SUBSTANCE are comets formed?

A. Comets are composed of a *transparent* or *translucent substance,* much more ethereal than the finest wisp of cloud.

Q. How is it KNOWN that they are composed of a thin, transparent substance?

A. Because generally stars of the faintest lustre remain perfectly visible through the densest portions of comets, although a slight fog is sufficient to completely obscure the light of faint stars.

Q. Are comets SELF-LUMINOUS, or do they shine by borrowed light?

A. Comets are supposed to shine by light which they have *received from the Sun.*

Comets grow brighter, and their tails increase in length, as they approach the Sun, until they are lost in his rays; after they pass their perihelion, they assume their greatest splendor, and then gradually decrease in brilliancy—thus showing that their light depends upon their proximity to the Sun. Yet, under certain conditions, comets have been observed to *increase* in brilliancy, when, according to the theory of reflected light, their splendor should *decrease.*

Q. Is the NUCLEUS of a comet, as well as its body and tail, composed of a GASEOUS MATTER?

A. It *is.* When the nucleus of a comet is viewed through powerful telescopes, it becomes *more and more misty,* instead of being more clearly defined, as it would be, if composed of a shining, solid substance.

Q. What is the NUCLEUS of a comet?

A. The *brighter point* in the centre of the head.

In some instances, a very minute star-like point has been observed in the nuclei of comets, but it is a rare occurrence. These *planetary nuclei*, as they are called, consist of nothing more than nebulous matter in a high state of condensation, but which cannot be regarded as solid bodies.

Q. Are the nuclei of comets ever very LARGE?

A. Some have been of *enormous dimensions.*

The following are the diameters (in miles) of the nuclei of some of the more remarkable comets since 1780:

			Miles.
Great comet of	1815, discovered by Olbers		5300
"	1825		5100
"	1843		5000
First comet of	1780		4270
"	1847, discovered by Hind		3500
"	1819, (July)		3280
Second "	1811, measured by Herschel		2640
Great "	1807,	" "	538
" "	1811,	" "	428
Second "	1798,	" Schroeder and Harding	125
"	1805, known as Biela's		70 to 112

The comet which was visible to the naked eye in June, 1845, had a bright nucleus, which must have been nearly 8000 miles in diameter, or about the size of our Earth.

Q. Is the comet's substance as LIGHT, or free from WEIGHT, as it is thin and transparent?

A. It is the *lightest ponderable* substance known to exist in space.

Q. What is the COMA of a comet?

A. The *nebulosity* or *atmosphere* which surrounds a highly condensed or planetary nucleus. The *nucleus* and *coma*, taken together, are called the *head.*

Q. The nuclei of comets are sometimes of great dimensions, and as they are the CENTRE of the head, the comet's head must sometimes be of enormous size: is this THE CASE?

A. It *is:* the great comet of 1811 had a nucleus of four hundred and twenty-eight miles in diameter, and a head the diameter of which measured *nearly five times the distance of the Moon from the Earth.* This comet had the largest head of any on record.

The diameters of the heads of some remarkable comets are given below:—

		Diameter of Head.
Great comet of	1811	1,125,000 miles.
Halley's "	1836	357,000 "
Encke's "	1828	312,000 "
First "	1780	269,000 "
" "	1846	248,000 "
Lexell's "	1770	204,000 "
Third "	1846	130,000 "
Second "	1849	51,000 "
First "	1847	25,500 "
Fifth "	1847	18,000 "

The size of the nucleus and coma of a comet is not constant and invariable, but subject to sudden and great changes. As an instance of their variability, Mr. Maclear, in January, 1836, at the Cape of Good Hope, saw a well-defined disc within the head of a

comet, which, from the apparent diameter assigned, could not have been less than 97,000 miles; but in the previous autumn, the very same comet had exhibited a brilliant nucleus, varying at different times from 250 to 1000 miles in diameter. The nebulosity of comets may extend much farther than we are able to distinguish from our point of observation on the Earth, and therefore our estimates of their true dimensions are probably very often underrated.

Q. Is the MASS of comets very great?

A. No: they have the *smallest mass* and *largest volume* of any members belonging to our system.

Q. Do comets CHANGE their APPEARANCE as they approach the Sun?

A. They do: in the larger comets the *nucleus* frequently grows *smaller* and *brighter*, and beautiful *trains of light* are generally seen to issue from the head in a direction opposite to, or away from the Sun.

Q. When do comets assume the GREATEST SPLENDOR of appearance?

A. Comets are more beautiful immediately *after their passage near the Sun.* They then shine with the brightest light, and have the longest tails.

> "With sweeping glories glides along in air,
> And shakes the sparkles from its blazing hair."—POPE'S HOMER.

Q. Do ALL comets have tails?

A. The *brighter comets* generally have tails, but the *telescopic* comets are usually without that appendage, and appear only as *roundish nebulosities.*

Q. Do comets generally have more than ONE tail?

A. No; but instances are recorded in which *more than one* tail has been observed.

The comet of 1744 is said to have had six tails; but this is only on the authority of Cheseaux. The best observers of Europe make no mention of the phenomenon, which they certainly would have done had they witnessed a sight so astonishing.

Q. Are comets ever visible in the DAYTIME?

A. *Sometimes they are.* The comet of 1843 was seen, the day after its perihelion passage, in full daylight, just before sunset, at Portland, Maine; from the deck of the ship Owen Glendower, then off the Cape of Good Hope; as well as at some places in South America and Southern Europe.

Q. To what CAUSE is the production of the comet's tail due?

A. The production of the tail is supposed to be due to the *approach* of the comet *towards the Sun.* It is evidently caused by the direct influence of the Sun, though no satisfactory reason has been assigned for its formation.

Q. What SINGULAR APPEARANCE has sometimes been seen in the tails of comets?

A. Apparent *vibrations* or *coruscations*, similar to the pulsations peculiar to the Aurora Borealis, have occasionally been seen in the tails of comets.

Q. How do these vibrations APPEAR?

A. They appear to *commence* at the *head*, and to traverse the *whole length of the tail* in a few seconds of time.

Q. Is the CAUSE of these vibrations connected with the NATURE of the comet?

A. No; these effects are attributed to the *constitution* of *our atmosphere.*

The reason given by Dr. Olbers for this phenomenon is, that the different portions of the tail of a large comet must be situated at widely different distances from our Earth, so that light would require several minutes more to reach us from one extremity than from the other. But this reasoning has been proved futile, the pulsations being almost instantaneous.

Q. Are the tails of comets formed SUDDENLY?

A. They *are* frequently formed *very rapidly.*

The comet of 1843 had a tail which at one time extended 200,000,000 of miles from the head. If the comet had at that time been in the plane of the ecliptic, and close to the Sun, the tail would have extended far beyond the orbit of the planet Mars, and probably have terminated in the region of the asteroids. Yet this wonderful appendage was formed in less than three weeks.

Q. Can the Sun's ATTRACTIVE POWER be the cause of the production of the tail?

A. It *cannot;* for gravitation would draw the tail *towards* the Sun, whereas that appendage usually *shoots* away from him. (*See Note* 39.)

Q. Do comets pass from great EXTREMES of HEAT and COLD in their orbits?

A. They *do;* for as comets move in more elongated ellipses than planets, they are subjected to *greater variations of temperature.* When in perihelion, some comets are so near the Sun as to be exposed to a heat much more intense than that of red-hot iron; and in aphelion they endure a temperature *several hundred degrees* colder than freezing water.

> "And feel by turns the bitter change
> Of fierce extremes; extremes by change more fierce;
> From beds of raging fire, to starve in ice
> Their soft ethereal warmth."—MILTON.

Q. Do comets MOVE very RAPIDLY?

A. Some comets move with great rapidity, others more slowly. They move more *quickly* when *near* to the Sun, and more *slowly* as they *recede* from it.

The comet of 1680 moved through its perihelion at the rate of 880,000 miles per hour.

Q. Is it not SURPRISING that bodies having so little mass as comets should move so rapidly?

A. It would be surprising, if their motions were performed through *a resisting medium* like our *air;* but the space through which comets travel is *almost void.*

Q Mention some of the most REMARKABLE comets.

A. The comets of 1680, 1811, 1843, and those known by the name of *Halley's* and *Biela's* comets, are the most remarkable on record.

Q. How large was the great comet of 1680?

A. Its tail extended over more than 70° of the heavens, and measured, according to Newton, no less than *one hundred and twenty millions of miles* in length.

It was the comet of 1680 which led Sir Isaac Newton to the study of *cometary astronomy.* The following figure is a representation of that wonderful object:

Fig. 102.

COMET OF 1680.

Q. What is the PERIOD of the comet of 1680? that is, how long does it require to perform ONE REVOLUTION round the Sun?

A. According to the calculations of Professor Encke, it would require *eight hundred and five years* to perform one revolution round the Sun.

If this calculation be correct, it may again be expected to be visible in our heavens about the year 2485!

Q. How FAR from the SURFACE of the SUN was the comet of 1680 during its perihelion passage?

A. It was only about *one hundred and fifty thousand miles* from the Sun's surface.

It was exposed to a heat, when nearest to the Sun, *twenty-seven thousand times* greater than that caused by his vertical rays in our torrid zone. It is probable that a degree of heat so intense would be sufficient to convert into vapor every terrestrial substance with which we are acquainted.

Q. How LARGE would the Sun appear, if viewed at the distance of the comet when in perihelion?

A. The Sun's diameter, if seen from the comet at the distance

of one hundred and fifty thousand miles, would appear about *seventy degrees* of angular measurement, or about *one hundred and forty times* larger than he appears to us.

The disc of the Sun, if viewed from that distance, would nearly fill the whole extent of the heavens, from the horizon to the zenith.

Q. How FAR from the Sun was the comet of 1680 supposed to be when at its APHELION?

A. Not less than *eighty thousand millions of miles.*

The orbits of some comets have been computed whose aphelion distance can not be less than 400,000,000,000 miles; and there are many whose orbits doubtless extend much farther.

"Hast thou ne'er seen the comet's flaming flight?
Th' illustrious stranger passing terror sheds
On gazing nations; from his fiery train
Of length enormous, takes his ample round
Through depths of ether; coasts unnumbered worlds
Of more than solar glory; doubles wide
Heaven's mighty cape; and then revisits Earth
From the long travel of a thousand years."—YOUNG.

Q. Is the comet of 1811 one of SHORT period?

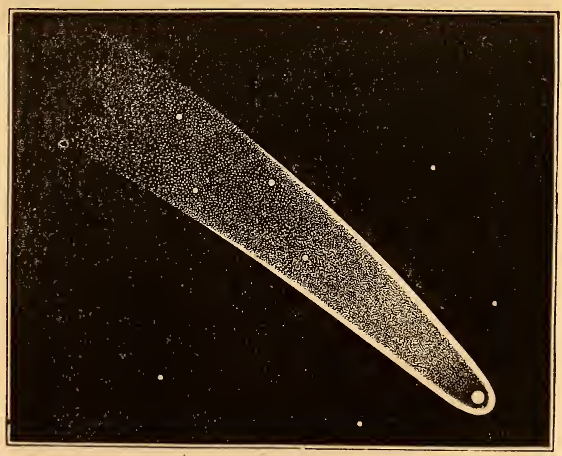
A. No; the comet of 1811 is supposed to require more than *three thousand years* for its revolution round the Sun.

Q. Are any comets supposed to have a LONGER PERIOD than 3000 years?

A. Yes; the comet which appeared in July, 1844, requires *more than one hundred thousand years* to perform its journey round the Sun.

The perihelion distance of the comet of 1811 was 98,700,000 miles, while its aphelion distance was computed to be 40,121,000,000 miles, or *fourteen* times the distance of the planet Neptune from the Sun.

Fig. 103.



The above figure represents the comet of 1811, with its envelope, which has been termed a head-vail.

Q. What APPEARANCE did the comet of 1811 present?

A. It presented a well-defined *planetary disc;* that is, its *nucleus* was so *bright*, and its edges so well-defined, that it had the appearance of the disc of a planet.

Upon applying very high magnifying powers, Sir William Herschel found the nucleus to vanish, the light being much diffused, though not uniformly.

Q. Was this bright nucleus accompanied by any OTHER APPEARANCE?

A. It *was involved or surrounded by a nebulosity*, which, together with the nucleus, formed the head.

Q. DESCRIBE the APPEARANCE of this nebulosity?

A. This nebulosity was an *envelope* which surrounded the head like a *vail.* Its *color* was a *blueish green*, that of the nucleus being of pale red.

Fig. 104.

The figure opposite represents the comet of 1843. It was observed at Chili, South America, to have a tail issuing from the side of the original one, at about 10° distance from the head, and extending to a much greater length than the first.—*Comptes Rendus des Sciences,* vol. xvii. p. 362.

Q. For what was the comet of 1843 REMARKABLE?

A. For the immense *length of its tail,* which was at one time computed to equal *two hundred millions of miles;* besides which it had a very bright nucleus.

Q. Describe the APPEARANCE of the nucleus?

A. It was *small,* but very bright, and of a *golden hue,* or *reddish,* as seen by some observers.

Q. Did the nucleus ever present a PLANETARY appearance?

A. It *did,* when brightest, exhibit a *planetary disc,* which was estimated to be at least 5000 miles in diameter.

Q. Did this comet approach NEAR the SUN?

A. The nearest distance which this comet approached the surface of the Sun was *ninety-six thousand miles.*

Q. With what RAPIDITY did the comet of 1843 move when at its perihelion?

A. It moved with the immense velocity of *three hundred and sixty-six miles per second!*

At that rate it would move 1,317,600 miles in an hour, which is five times the distance of the Moon from the Earth. The whole of that segment of its orbit situated above the plane of the ecliptic in which the perihelion point was situated, was described by the comet in a little more than *two hours.*

Q. Is the comet of 1843 supposed to be PERIODICAL?

A. It *is;* some of the best computations assign to it a period of *three hundred and seventy-six years.*

Q. Why is HALLEY'S COMET so called?

A. It was thus designated in honor of *Edmund Halley,* a great English astronomer, who first accurately computed its elements in the year 1682.

Q. Of what UTILITY were these observations and calculations of Halley?

A. They served as *data* whereby to *identify* the comet with others which had appeared before.

Q. How was this ACCOMPLISHED?

A. Halley compared its *elements,* that is, its *perihelion distance,* its *longitude of perihelion, longitude of its ascending node, inclination of its orbit,* and *time of its perihelion passage,* with the elements of former comets.

Q. What CONCLUSION did Halley arrive at?

A. That it performs its journey round the Sun once in about *seventy-five years,* and believed it to be identical with the comets of 1456, 1531, and 1607.

Q. Halley predicted that the comet of 1682 would return again in about seventy-five years: was his prediction VERIFIED?

A. It *was;* the comet was seen again in 1759.

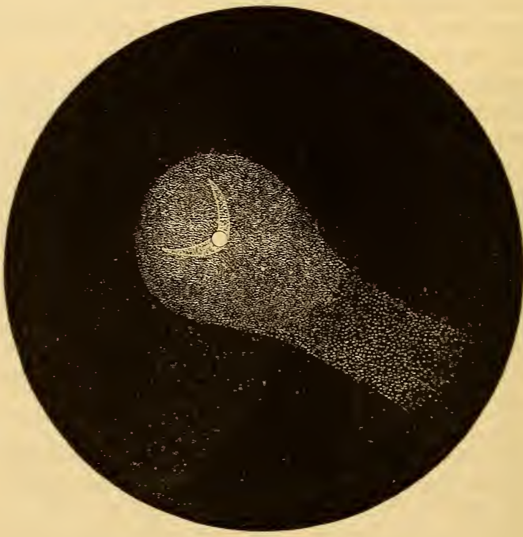
Halley's comet was the first whose return was successfully predicted, and whose orbit was accurately determined. (*See Note* 40.)

As Halley could not hope to live to see his prediction fulfilled, he requested that astronomers might look for the comet at the designated time; and should it appear, he was desirous that the world might remember that it was an Englishman who had foretold its return. His name is associated with the comet, the discovery of whose period forms so memorable an epoch in the history of the science.

Q. Has Halley's comet been seen SINCE 1759?

A. Yes; in about 76 years after, that is, in the year 1835, it made its last appearance, and will not return to our view again until about the year 1911.

Fig. 105.



Q. Had Halley's comet a TAIL when it was seen in 1835?

A. When it was *first seen* in August of that year it had *no indications of a tail;* but towards the end of September a tail became *gradually visible*, and by the middle of October of the same year, it attained its *greatest length.*

Q. What APPEARANCE did Halley's comet present in the year 1835?

A. It is described as having at one time the appearance of a *powder-horn.* Professor Struve compares the nucleus to a *fan-shaped flame*, emanating from a bright point; this flame afterwards changed its appearance, and resembled a *red-hot coal* of an oblong form. At another time it appeared like the *stream of fire* which issues from a cannon's mouth after its discharge.

At its nearest approach to the Sun this comet was 55,900,000 miles from his centre; and at its aphelion, or greatest distance from that luminary, it was 3,370,300,000 miles from his centre, which is a distance exceeding that of the planet Neptune.

Q. Who was the DISCOVERER of Biela's comet?

A. It is not *known* who was the discoverer; it was recorded as first seen in the early part of the eighteenth century. But it is thus called in honor of M. Biela, of Josephstadt, in Bohemia, who computed its elements, and found it to be a *comet of short period.*

Q. What is the PERIOD of Biela's comet?

A. It describes its journey round the Sun in a very eccentric ellipse, in about *six years and seven months.*

Q. Is this comet a CONSPICUOUS object in the heavens?

A. No; it is *small*, and *hardly visible* to the naked eye, even when brightest.

Q. Why, then, is this comet REMARKABLE?

A. It is worthy of note as being a *periodic* comet; and also for the *singular phenomenon* which struck every astronomer with astonishment at its appearance in the year 1846.

Q. What was this SINGULAR PHENOMENON?

A. It was seen to *separate into two distinct parts or separate comets.*

Euphorus, a Greek author who lived more than 300 years before Christ, mentions a comet which, before vanishing, was seen to divide into two distinct bodies. Hevelius states that Cysatus perceived in the nucleus of the comet of 1618 an evident inclination to separate into fragments, which at one time bore a strong resemblance to an assemblage of small stars.

Q. Was the change observed in Biela's comet SUDDEN?

A. Yes; it was supposed to have separated within the space of *two weeks.*

The change was discovered by Lieutenant Maury, at the National Observatory at Washington, on the 12th of January, 1846; but was not observed in Europe until three days after, when it was seen by the Rev. Mr. Challis, of Cambridge, England, and M. Winchmann, of Kœnigsberg.

Q. How does Lieutenant Maury describe the APPEARANCE of this comet?

A. The comet which separated from the original one had a *bright* and *starlike nucleus*, resembling a *diamond spark.* An apparent *connection* was maintained between the two, by means of a *train of light* from the larger to the smaller.

Q. When this comet separated, did the two parts continue to JOURNEY TOGETHER?

A. Yes; the two parts moved along together for some time, at the distance of *one hundred and fifty thousand miles* asunder.

At its appearance in 1852, the two parts of the comet were more than 1,250,000 miles asunder. This comet's greatest distance from the Sun is estimated at 590,100,000 miles, and its perihelion or least distance, at 81,600,000 miles.

Q. Does the orbit of Biela's comet APPROACH the ORBIT of the EARTH?

A. By a remarkable coincidence, this comet, in the year 1832, came so near the Earth that if it had been retarded *one month* in its orbit, it would have come in *collision* with the Earth. But it did not approach nearer the Earth than *several millions of miles.*

Sir John Herschel says—"The orbit of this comet approaches very near that of the Earth; and had the latter, at the time of its passage in 1832, been a month in advance of its actual place, it would have passed through the comet—a singular rencontre, perhaps not unattended with danger."—*Herschel's Astronomy*, p. 309.

Q. What is there REMARKABLE about the comet of 1770?

A. This comet in its journey towards the Sun approached *so near* the planet Jupiter, that it remained in its vicinity about four months; yet it had no *perceptible influence* on Jupiter's satellites.

Q. Did that comet approach very near the EARTH?

A. Its approach was so near the Earth, that had its mass been equal to the mass of the Earth, its attractive force would have been sufficient to have *increased* the orbit of the Earth, and consequently *lengthened* its time of revolution.

Q. Had the comet's mass been equal to the mass of the Earth, how much would it have increased the LENGTH of our YEAR?

A. It would have increased the length of the year nearly *three hours.*

Q. Did it LENGTHEN the period of our year?

A. No; it did not produce any *sensible effect* on the length of the year; therefore its mass could not have exceeded the *one five-thousandth* part of the Earth's mass. Its nearest approach to the Earth did not have the slightest effect on our tides.

Q. What NAME has been assigned to the comet of 1770?

A. It is generally called *Lexell's* comet, from the great mathematician who labored in following and discovering its perturbations.

Q. Did the ORBIT of Lexell's comet CHANGE?

A. Yes; previous to the year 1767 it moved in an elongated orbit, requiring nearly fifty years to accomplish one revolution round the Sun; but owing to coming within the influence of Jupiter's attraction, its orbit was reduced to a small ellipse, in which the comet in the year 1770 revolved round the Sun in *five and a half years.*

Q. In what kind of orbit does Lexell's comet move AT PRESENT?

A. It is *not known;* for owing to the superior attraction of the planet Jupiter, its orbit is entirely *changed* or *deflected*, and thereby is *lost* to our sight forever, unless it experiences some other change by approximation to one of the planets. (*See Note* 41.)

"Lone traveller through the fields of air,
What may thy presence here portend?
Art come to greet the planets fair
As friend greets friend?

"Whate'er thy purpose, thou dost teach
Some lessons to the humble soul:
Though far and dim thy pathway reach,
Yet still thy goal

'Tends to the fountain of that light
From whence thy golden beams are won;
So should we turn, from Earth's dark night,
To God, our Sun."—MRS. HALE.

CHAPTER XIII.

Systems of Astronomy.

Q. What is MEANT by a system of astronomy?

A. The *arrangement* of the *planetary system* according to the theory of certain astronomers.

Q. What is UNDERSTOOD by a planetary system?

A. By a planetary system the ancients understood the *disposition* and *course* of *seven planets* with regard to our Earth.

Q. What is understood by the term SOLAR SYSTEM?

A. The *Sun*, with the *primary* and *secondary* planets and *comets* revolving around it.

By a solar system, in a more extended sense, is understood any *fixed star* with a number of spheres revolving around it as planets.

SECTION I.

Ptolemaic System.

Q. Who was PTOLEMY?

A. He was an *astronomer* of *Alexandria*, who lived about A.D. 150.

Q. Had he CORRECT notions with regard to the arrangement of the bodies belonging to our system?

A. He had *not.*

Q. What BODY did he imagine to be the CENTRE of the system?

A. He conceived the *Earth* to be the grand centre of the whole planetary system.

Q. Was this system of astronomy FIRST promulgated by Ptolemy?

A. No; the system which is called Ptolemaic is wrapped in the obscurity of very *high antiquity:* its origin is unknown.

Fig. 106.—PTOLEMAIC SYSTEM.

Fig. 106 represents the solar system according to Ptolemy. The Earth is immovably fixed in the centre, around which are twelve circles. The first seven of these circles represent the orbits of the following bodies, thus: First, the Moon; next, Mercury; then, Venus; fourth, the Sun; fifth, Mars; sixth, Jupiter; and seventh, Saturn. The eighth circle, *e*, represents the sphere of the fixed stars; the ninth, *d*, and tenth, *c*, called the first and second crystal heavens, were imagined by Ptolemy as necessary to account for certain phenomena which he could not otherwise explain. The eleventh circle, *b*, he called the Primum Mobile, which, he supposed, carried the other ten circles enclosed in it, in its daily rotation from east to west; while the twelfth and last circle, *a*, Ptolemy indicated by the name of Empyreum, or the abode of spirits and the blessed.

Q. Was the system of Ptolemy BELIEVED in for a long time?

A. It was received by *many* as the true system until the middle of the *fifteenth* century.

SECTION II.

The Egyptian System.

Q. What was the EGYPTIAN SYSTEM?

A. The *system* of the *universe* as believed in by the Egyptian astronomers.

The Ptolemaic system was denounced by the Egyptian astronomers as erroneous, because the superior conjunctions of the inferior planets Mercury and Venus could not be accounted for by that theory. For as (according to Ptolemy) their orbits were between the Earth and the Sun, there could be no reason assigned for their appearance beyond that luminary, or, what is the same thing, their superior conjunction.

Q. What was the CENTRE of the Egyptian system?

A. The Earth was the centre, and first the Moon and then the Sun revolved around it.

Fig. 107.—THE EGYPTIAN SYSTEM.

Fig. 107 represents the bodies of our system according to the theory of the Egyptian astronomers. The Earth is the centre, and the Moon and Sun revolve around it in circular orbits. Venus and Mercury, however, revolve round the Sun, and are carried with him around the Earth. Mars, Jupiter, and Saturn revolve in orbits far distant: and beyond the orbit of Saturn is the region of the fixed stars.

SECTION III.

Tychonic System.

Q. Who was the FOUNDER of the Tychonic system?

A. *Tycho Brahé*, an astronomer who lived in the second half of the sixteenth century.

Q. What was his THEORY of the solar system?

A. His *reason* dictated the theory of the Sun as the centre, and the planets, with our Earth, revolving round him. But he placed the *Earth* in a *fixed spot*, with the Moon revolving round it, and the Sun as the centre of the orbits of the other planets.

Tycho Brahé's reason for teaching against his better judgment was, that he believed it contrary to Scripture that the Earth should move. He therefore, like the other

theorists, placed in the centre of the universe, with the Moon revolving round it first, and then the Sun; round this latter body, the planets Mercury, Venus, Mars, Jupiter, and Saturn revolve as their centre.

FIG. 108.—TYCHONIC SYSTEM.

Fig. 108 represents the solar system, according to Tycho Brahé.

Longomontanus, the friend and disciple of Tycho, supported an hypothesis different from either of those above mentioned, and approaching nearer to the truth. He maintained, with Ptolemy, that the Earth was the centre of the universe; and with Tycho, that all the planets revolved round the Sun, which is placed in one of the foci of their elliptical orbits; but he held that the diurnal motion of the heavenly bodies arose from the rotation of the Earth upon its axis, and thus got rid of one of the strongest objections to the system of his friend and master.

SECTION IV.

The Copernican System.

Q. When was the Copernican system FIRST TAUGHT?

A. It was known and taught by *Pythagoras*, who flourished about B. C. 500.

Q. Why is it called COPERNICAN?

A. Because the system taught by Pythagoras was lost, and was not restored until the fifteenth century, when it was again taught by *Nicholaus Copernicus*, a Polish philosopher.

Fig. 109.—COPERNICAN SYSTEM.

Fig. 109 represents the *true*, or Copernican, system, with the Sun in the centre, and the planets and comets revolving around him.

Q. What is the ARRANGEMENT of the solar system as taught by Copernicus?

A. He taught that the Sun is the *centre* of the system, and that the *planets*, including our *Earth*, *revolve around him.*

Although this theory has been proved to be the true one, yet when first promulgated by Copernicus, it had many opponents. His substitution of the annual and diurnal motion of the Earth, they thought reasonable; but his making the Earth and the whole terrestrial orbit shrink into a mere point in comparison with nearly all the other heavenly bodies and their respective orbits, was too sudden a demolition of long-nurtured opinions to obtain extensive credit. But now the truth of this theory has been tested and firmly established by the observations of Galileo, Kepler, Newton, and others, although the theory as promulgated by Copernicus was afterwards much modified by the last-named astronomers. The system, however, still bears the name of the Copernican.

PART III.

Sidereal Astronomy.

"And canst thou think, poor worm! these orbs of light,
In size immense, in number infinite,
Were made for thee alone?"

Q. What is SIDEREAL ASTRONOMY?

A. Sidereal Astronomy treats of *all those celestial bodies not included in our solar system.*

Q. What are those celestial bodies which are not members of our solar system CALLED?

A. They are generally known by the name of *fixed stars.*

Q. Why are they called FIXED STARS?

A. Because they are *fixed*, or retain the same *general positions* with regard to each other.

This is not strictly true; for all the fixed stars are supposed to have motion, though it is too minute to be perceptible, except with very delicate instruments, and by a series of observations continued through a long lapse of years.

Q. How are the fixed stars DISTINGUISHED from the bodies belonging to the solar system?

A. They do not shine by borrowed light; but, like our Sun, shine by their *own native light.*

Q. How is it known that they shine by their OWN LIGHT?

A. Stellar, like solar light, is wholly *unpolarized*, while every reflected light, celestial or terrestrial, is possessed of such properties as are acquired only through polarization.

Q. Is there any OTHER CHARACTERISTIC by which the fixed stars may be known?

A. The fixed stars may also be known by their *scintillation* or *twinkling;* but the planets shine with a more *steady* light.

The scintillation or twinkling of the stars is owing to the sudden changes in the refractive powers of the different strata of our atmosphere, which, if they had perceptible discs like the planets, would not be sensible.

Q. What is meant by the STELLAR UNIVERSE?

A. By the stellar universe is meant all the *celestial bodies* not included in our solar system.

Q. Are the bodies belonging to the stellar universe very REMOTE?

A. Yes; they are situated so far from our Sun that their distances are *inconceivably great.*

CHAPTER I.

The Fixed Stars.

"The stars are the landmarks of the universe; and amid the endless and complicated fluctuations of our system, seem placed by their Creator as guides and records, not merely to elevate our minds by the contemplation of what is vast, but to teach us to direct our actions by reference to what is immutable, in his works."—*Sir John Herschel.*

"What involution! what extent! what swarms
Of worlds! that laugh at Earth! immensely great!
Immensely distant from each others' spheres;
What, then, the wondrous space through which they roll
At once it quite engulfs all human thought;
'Tis contemplation's absolute defeat."—YOUNG.

Q. How many of the heavenly bodies which are visible to the naked eye may be considered as PLANETARY BODIES?

A. *Venus*, *Mars*, *Jupiter*, *Saturn*, and *our Moon* are the only planetary bodies which are usually visible to the unassisted eye.

Q. What are the other stars visible to the naked eye CALLED?

A. They are called *fixed stars.*

Q. Why are they called FIXED STARS?

A. Because they are never seen to *wander* or move about *among each other*, like the planets and our Moon.

Q. Are the fixed stars of any USE to man?

A. They are a *guide* to the *traveller* by land, and *direct* the *course* of the *navigator* through the trackless ocean. They serve for "signs and for seasons, and for days and for years."

By the observations of the relative situations of the stars, we are enabled to determine our days and years with the utmost accuracy. The stars are our most perfect chronometers. We have, by their assistance, measured the circumference of our globe, and determined the positions of all places on its surface.

Q. Are the fixed stars without ANY MOTION with regard to each other?

A. They are all subject to *slight amounts* of motion; but it requires the nicest instruments to be able to detect it.

Q. What are the APPARENT DIMENSIONS of the fixed stars?

A. The fixed stars are all *without apparent diameter.* They are fixed *points* of light without measurable dimensions.

Q. Why are the fixed stars WITHOUT measurable dimensions?

A. Their visible forms are mere points, too small to admit of angular measurement, even when seen through the most powerful telescopes.

The eye is capable of perceiving very minute objects. Hueck states that spiders' threads, that measure less than a second in diameter, may be distinguished by the eye; yet a star is entirely *concealed* when passing behind the finest spider's thread. Dr. Wollaston contrived a means of drawing out platinum wire so fine that one hundred and fifty might be bound together before one filament was produced as thick as the silkworm's fibre; and that thirty thousand of them could be laid side by side within the length of one inch; yet Dr. Wollaston's wire can more than cover the point of even the brightest fixed star.

Fixed stars are the smallest visible objects ever seen by the naked eye. They can be perceived, notwithstanding their very minute dimensions, on account of the intense brilliancy of their light, and the absolute blackness of the background of space in which they appear.

Q. Do ALL the fixed stars shine with EQUAL brightness?

A. No; the brightest fixed stars visible to the naked eye shine with *two hundred times* more light than the faintest.

Q. How MANY stars does the naked eye perceive in the nocturnal sky?

A. About *two or three thousand* stars are visible to the naked eye; but when we view the heavens with a telescope, their number extends to *many millions.*

The number of stars distinctly visible in both hemispheres in a twenty-feet reflector is nearly five and a half millions. That the actual number is much greater, there can be no doubt, when we consider that some portions of the milky way are so thickly studded with stars that it is impossible to count them.

> "Survey this midnight scene:
> What are Earth's kingdoms to yon boundless orbs—
> Of human souls, one day, the destined range!

Q. How are the fixed stars CLASSIFIED as regards their BRILLIANCY?

A. They are divided into orders or classes, thus: those which appear the brightest to the naked eye have been called stars of the *first magnitude;* those which appear next in brilliancy, of the *second magnitude;* and so on.

Q. But are the brightest stars REALLY LARGER and NEARER than those which are less brilliant?

A. *No;* the brightness of a star is no criterion whereby to judge of its distance.

Q. Why, then, are the stars said to be of the first, second, third, &c. MAGNITUDE?

A. The term magnitude is merely *arbitrary,* and is used by astronomers to indicate the *apparent quantity of light* emitted by those bodies.

The term *magnitude* was not always used, for we find Leonard Digges, who lived in the sixteenth century, speaks of "starres of the *first lyghte.*"

Q. How many of these stars are of FIRST-CLASS brightness?

A. About *twenty* of the fixed stars are of the first-class, or stars of the first magnitude.

Q. What are the SMALLEST stars discernible by the naked eye?

A. No stars *smaller* than the *sixth class* can be discerned by ordinary vision without a telescope.

Q. Are the stars which cannot be seen by the naked eye CLASSIFIED?

A. Many of them are: all stars smaller than the sixth magnitude are called *telescopic stars.*

Q. What ARE the fixed stars?

A. The fixed stars are *immensely large bodies*, shining, as the Sun does, by their *own inherent light.*

The quantity of light emitted by many of the fixed stars proves that they must be situated at immense distances from our system. By the experiments of Dr. Wollaston, it has been found that the light of the Sun is equal to eight hundred thousand full moons, and about twenty millions of millions of times greater than that of Sirius, the brightest of the fixed stars.

Q. How are the fixed stars DESIGNATED from each other?

A. There are catalogues and maps made of all the principal stars, amounting to about 20,000; and the stars belonging to each group are designated by the *letters* of the *Greek alphabet;* after which the *Roman alphabet* is used; and lastly, *figures.*

The Greek Alphabet.

α	Alpha,	a.	ν	Nu,	n.
β	Beta,	b.	ξ	Xi,	x.
γ	Gamma,	g.	ο	Omicron,	o short.
δ	Delta,	d.	π	Pi,	p.
ε	Epsilon,	e short.	ρ	Rho,	r.
ζ	Zeta,	z.	ς σ	Sigma,	s.
η	Eta,	e long.	τ	Tau,	t.
θ	Theta,	th.	υ	Upsilon,	u.
ι	Iota,	i.	φ	Phi,	ph.
κ	Kappa,	k.	χ	Chi,	ch.
λ	Lambda,	l.	ψ	Psi,	ps.
μ	Mu,	m.	ω	Omega,	o long.

Q. What are the fixed stars SUPPOSED TO BE?

A. The fixed stars are supposed to be *suns* like ours, and the centres of *planetary worlds.*

Q. If our Sun is one of the fixed stars, why does it appear so LARGE and BRILLIANT?

A. Because our Sun is comparatively *near* to us; if it were removed to the distance of the *nearest* fixed star, it would appear only like a *brilliant point.*

SECTION I.

Apparent Motions and Positions of the Stars.

"Ye stars which are the poetry of Heaven."—BYRON.

Q. What is the SKY?

A. The visible portion of the *expanse of space* surrounding the Earth.

Q. Why does the sky look as if it were a CONCAVE SURFACE?

A. Because the eye sees to an *equal* distance in all directions.

Q. On turning the eyes upwards, what is the BOUNDARY of vision?

A. The *apparent surface* of the sky.

Q. Why does the sky appear BLUE in a cloudless day?

A. Its blue color, during the day, arises from the *atmosphere reflecting* the blue rays of light. It is properly the *air* which is blue.

Q. Why do the NOCTURNAL HEAVENS assume the appearance of a CONCAVE surface?

A. Because the stars seem all to lie at *equal distances* from the Earth.

Q. What causes the APPARENT MOTION of the heavenly bodies?

A. The *apparent* motion of the heavenly bodies is due to the *real* motion of the Earth.

Q. Why do the Sun, Moon, and stars seem to MOVE along continually, from east to west, in the concave surface of the heavens?

A. Because the Earth's surface, whereon the observer stands, is as constantly carried along in the *opposite direction*—that is, from west to east—in consequence of the Earth's rotation on her axis.

Q. How FAR do the heavenly bodies seem to move their positions during the lapse of an hour?

A. The heavenly bodies apparently change their positions *fifteen degrees* of angular motion every hour.

Q. How is it PROVED that the stars have an apparent angular motion of fifteen degrees per hour?

A. The Earth revolves on its axis once in twenty-four hours; therefore in one hour it accomplishes the twenty-fourth part of its rotation. As the whole circle of rotation comprises three hundred and sixty degrees, the twenty-fourth part of three hundred and sixty degrees would be the amount it would move in one hour. The twenty-fourth of three hundred and sixty degrees is fifteen degrees, which is the Earth's hourly motion, and the *apparent* motion of the stars.

Q. Do the stars seem to move in circles that RISE VERTICALLY from the east and DESCEND VERTICALLY towards the west?

A. It is only at the *equinoctial regions* of the Earth that the stars seem to rise vertically from the east, and descend vertically towards the west.

Q. Why do not the stars seem to RISE VERTICALLY from the horizon in any latitudes except the equinoctial regions?

A. Because the points round which the surface of the celestial sphere seems to revolve are not placed in our *horizontal circle.*

Q. What are the POINTS around which the celestial bodies appear to move?

A They are the *poles* of the heavens.

Q. What ARE the POLES of the heavens?

A. The celestial poles are the *axis* of the Earth *extended to* the

celestial sphere. They are situated ninety degrees from the equinoctial. That conspicuous star within a degree and a half of the north pole is called the pole star.

Q. Where would the POLES of the heavens appear to an observer situated at the EQUATOR?

A. The poles of the heavens would appear in the *horizon* of an observer at the equator.

Q. Where would the EQUATOR appear to an observer at the POLES of the Earth?

A. The equator would be in the *horizon* of an observer situated at the poles.

Q. Why would the POLES appear in the HORIZON to an observer at the equator, and the EQUATOR in the horizon to an observer at the poles?

A. Because the horizon extends 90° each way from an observer wherever he may be situated; and as the poles are 90° from the equator, they would appear in the horizon of a person at the equator; for the same reason the equator would appear in the horizon to a person at the poles.

Q. Where would the POLE appear to a person situated in latitude 45°, or half-way between the equator and the poles?

A. To a person half-way between the equator and the poles the pole would appear *half-way* between the *zenith* and *horizon.*

Q. What is the LATITUDE of a place?

A. It is the *distance* from the *equator* north or south.

Q. How may the LATITUDE of a place be FOUND?

A. By observing the *altitude of the pole above the horizon.*

Q. Explain this.

A. If the altitude or elevation of the *north* pole above the horizon be found to be 20°, the latitude of that place is 20° *north;* if the *south* pole be observed to be elevated 20°, the latitude is the same number of degrees *south* of the equator.

Q. When the Sun is vertical at the tropic of Cancer, which is 23½° north of the equator, how does he APPEAR to the inhabitants under the ARCTIC CIRCLE?

A. About the middle of June, when the Sun is vertical at the tropic of Cancer, the inhabitants who live under the arctic circle see him nearly at the *east* point of their horizon at six in the morning; at noon he will be near midway between the *south* point of the horizon and the *zenith;* at six in the evening he will be near the *west* point; and at *midnight* he will be seen on or near the *north* point of the horizon.

Q. Do the APPARENT POSITIONS of the fixed stars undergo any CHANGES?

A. *Yes;* their positions appear to change from several causes.

Q. What causes the CHANGES in the apparent positions of the fixed stars?

A. The apparent positions of the fixed stars are affected by *six separate causes* of variation.

Q. What are the SIX SEPARATE CAUSES which produce a slight change in the apparent positions of the fixed stars?

A. The apparent places of the fixed stars are slightly changed by *precession*, *nutation*, *refraction*, *aberration*, *proper motion*, and *parallax.*

DIVISION I.—PRECESSION.

Q. What is PRECESSION?

A. A *retrograde motion* of the equinoctial points.

Q. What are the EQUINOCTIAL POINTS?

A. The *two points* where the celestial equator is *intersected* by the ecliptic, are called *equinoctial points.*

When the Sun is in either of these points, the days and nights are equal to each other in every part of the globe.

Q. Are the equinoctial points FIXED with respect to the stars?

A. No; they possess a *retrograde* or *westerly motion*, contrary to the order of the signs.

Q. What is this retrograde motion CALLED?

A. It is called the *precession of the equinoxes.*

Q. WHY is it called the precession of the equinoxes?

A. Because the position of the equinox in any year *goes before* or *precedes*, in the order of the signs, the place which it occupied in the previous year.

Q. What PRODUCES the precession of the equinoxes?

A. The motion of the *Earth's axis* round the *poles* of the *ecliptic.*

Q. What PRODUCES the revolution of the pole of the equator round that of the ecliptic?

A. It is produced by the *combined action* of the Sun and Moon on the *redundant matter* at the equator of the Earth, by which its figure is rendered spheroidal.

Q. At what RATE is the retrograde motion of the equinoxes?

A. At the rate of about one degree in *seventy years*, or of fifty seconds annually.

Q. What EFFECT has the precession of the equinoxes upon the apparent positions of the stars?

A. Precession *increases* the *longitudes* of the stars.

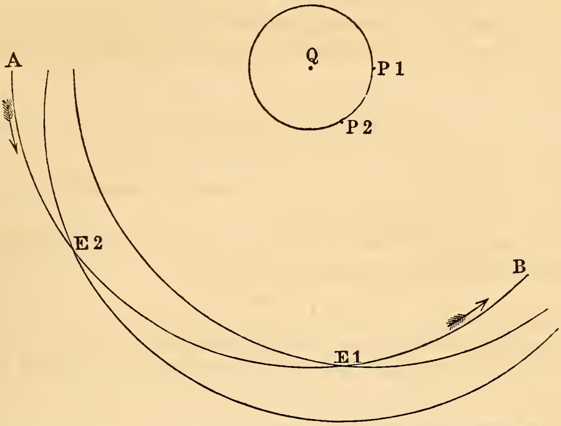
Q. Why does precession INCREASE the longitudes of the stars?

A. Because longitude is reckoned from the point called the *vernal equinox*, and a retrogradation of this point on the ecliptic must *increase* the *angular distance* of a star.

Q. How LONG does it take for the pole of the equator to perform a revolution round the pole of the ecliptic?

A. This revolution, performed in a path scarcely differing from a circle, requires no less than *twenty-five thousand eight hundred and sixty-eight years*, in which interval the *equinoxes complete an entire circuit* of the heavens.

Fig. 110.



Suppose Q to be the pole of the ecliptic, and the small circle to be the path traced out by the pole of the equator in the course of its revolution around Q; also let A B represent a part of the ecliptic, the arrows indicating the order of the signs, or the direction of the Sun's apparent motion. When the pole of the equator is at P 1 the equinoctial point will fall at E 1; but when the pole, in its westerly course, arrives at P 2, the equinox will have fallen back from E 1 to E 2. It will have moved contrary to the Sun's apparent motion, so that the point from which we reckon longitudes on the ecliptic, and right ascensions on the equator, must occupy a position among the stars, when the pole of the equator is at P 2, *behind* that which it possessed at the time the pole was at P 1; and as the stars do not really participate in this movement, their longitudes are necessarily increased from year to year.

Q. Was the pole star ALWAYS situated within a degree and a half from the north pole?

A. No; in the earlier periods of astronomical observation it was situated *twelve degrees from the celestial pole.*

The pole star is at this time *one degree, twenty-seven minutes* from the true pole.

Q. Will it ALWAYS retain its PRESENT POSITION with respect to the pole?

A. No; its position is *always changing*, though extremely slowly. It will continue to approach the pole until within half a degree of it, after which it will recede from the pole for thousands of years.

In rather more than 12,000 years the bright star Wega, in the constellation Lyra, will be within five degrees of the pole, and will be the pole star of the northern hemisphere. (*See Note* 42.)

DIVISION II.—NUTATION.

Q. What is NUTATION?

A. The attraction of the Moon upon the spheroidal figure of the Earth gives rise to a *slow motion of her axis to and fro*, which, from its oscillatory character, has been termed *nutation.*

Q. Does nutation produce any effect on the EQUINOCTIAL POINTS?

A. It produces a slight *advance* and *return* of the equinoctial points, occurring alternately about every nineteen years.

Q. What EFFECT has this alternate changing of the equinoctial points upon the apparent positions of the fixed stars?

A. It *increases* and *diminishes* the longitudes and right ascensions of the fixed stars alternately, in an interval of nearly nineteen years.

Q. What APPARENT MOTION does nutation produce?

A. It makes the pole of the heavens appear to *revolve* in a *small ellipse* once in about every nineteen years.

Q. Why does the celestial pole appear to perform a revolution ONCE IN NINETEEN YEARS?

A. Because the *Moon's attraction* goes through all its *variations* once in nineteen years, which period is called a *cycle of the Moon.*

Q. But owing to the precession of the equinoxes the pole of the equator moves round the pole of the ecliptic: has the equatorial pole ANY OTHER motion?

A. Yes; it undergoes the oscillatory motion arising from the nutation of the Earth's axis; whence it appears its true course will be in a wavelike curve.

Fig. 111.

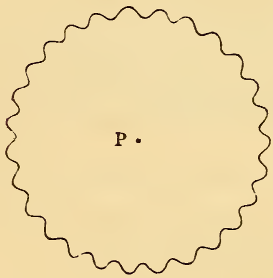


Fig. 111 represents, though highly exaggerates, this wavelike curve, the centre of which marked P, is the pole of the ecliptic. (*See Note* 43.)

DIVISION III.—REFRACTION.

Q. What is the ATMOSPHERE?

A. The *fluid* which we *breathe,* and which *surrounds* the globe.

Q. What is the HEIGHT or THICKNESS of the atmosphere?

A. Its limit is not *accurately known,* but it cannot be less than *forty miles* high.

Q. Is the DENSITY of the atmosphere the SAME throughout its whole extent?

A. No; its density *diminishes* as its *height increases;* that is, it is more *dense* near the *surface* of the Earth than at a considerable elevation above it.

Q. Why is the KNOWLEDGE of the CONSTITUTION of the atmosphere important to the astronomer?

A. Because, like all transparent media, it possesses the power of *refracting* or *bending* the rays of light out of a *straight course.*

Q. What EFFECT is produced by the rays of light being refracted or bent?

A. Objects seen *obliquely* through the atmosphere do not appear in their *true places.*

Q. How can this be EXPLAINED?

A. It is an established law in optics, that when a ray of light passes from a rare medium into one of greater density, it is *deflected* or *bent* from its original course.

Q. When a ray of light passes from a rare medium into one of greater density, in what DIRECTION is it bent?

A. It is bent more and more *towards the perpendicular* as the medium through which it passes *increases* in density.

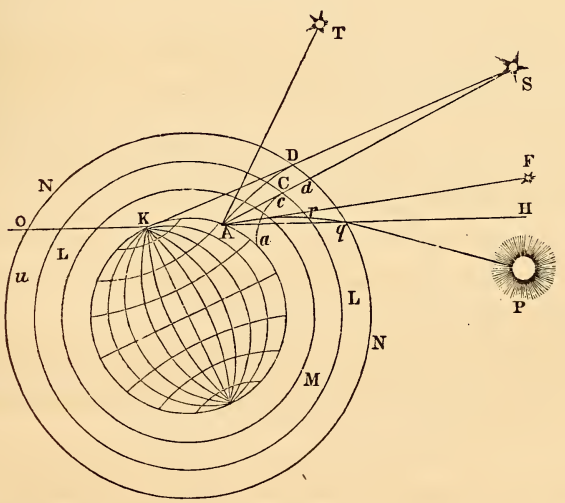
Q. What is the EFFECT produced on a ray of light passing through the Earth's atmosphere?

A. As it approaches the surface of the Earth it continually encounters a *denser medium* than that which it has already passed through; consequently it is *bent* more towards the *perpendicular.*

Q. When a ray of light from a heavenly body reaches the eye of a spectator, does the body appear in its TRUE PLACE?

A. No; it appears *higher up* from the horizon than it really is, owing to the rays of light being bent more towards the *perpendicular.*

Fig. 112.



Let a spectator be placed at A, any point of the Earth's surface, and let L M N represent the successive strata of the atmosphere, increasing in density as they approach the Earth. Let S be a star or other heavenly body, far without the limits of our atmosphere; if the air were removed, the spectator would see it in the direction of the straight line A S. But when the ray of light S A reaches the atmosphere at *d*, it will, by a law of optics, be bent downwards, and take a more inclined direction, as *d c*, and reach the Earth at the point *a*. But this ray will not strike the eye of the spectator.

The ray which will enable him to see the star is not S *d* A, but another ray, which, had there been no atmosphere, would have struck the earth at K, a point behind the spectator, but which, being refracted by the atmosphere into the curve S D C A, actually strikes on A. An object is always seen in the direction which the visual ray has at the instant of arriving at the eye. Hence the star S will be seen at T in the line A T, a tangent to the curve S D C A. Thus it will be seen that the refractive power of the atmosphere causes all heavenly bodies to appear more elevated than they would were there no atmosphere. Therefore the Sun when at P, below the horizon H A O of the spectator at A, appears in the line A F, being bent in the curve P *q r* A, to which A F is a tangent.

Q. What is the phenomenon of seeing a heavenly body in a direction different from the true one CALLED?

A. It is called *refraction.*

Q. Do celestial objects EVER appear to us in their TRUE PLACES?

A. Yes; those bodies *immediately overhead* always appear in their true place, for in the zenith there is *no refraction.*

Q. Why is there NO REFRACTION of the rays of light coming from an object in the ZENITH?

A. Because a ray of light, coming from the zenith, falls *perpendicularly* on the surface of the Earth; and as refraction only tends to *bend it* towards the perpendicular, it follows that an object situated in the zenith is seen in its *true place.*

Q. Where is the amount of refraction the GREATEST?

A. The amount of refraction is the greatest at the horizon.

Q. What is the AMOUNT of refraction at the horizon?

A. The amount of refraction at the horizon is rather more than *thirty-five minutes* of angular measurement.

Q. Explain this.

A. Any object—a fixed star, for instance—when really *below* the horizon, would appear to be *thirty-five minutes above it*, and consequently *still in sight.*

Q. Do the Sun and Moon appear ABOVE the horizon after they REALLY HAVE SET?

A. Yes; both the Sun and Moon appear to be *wholly above* the horizon when they are *really below it.*

Q. What is the EFFECT, then, of refraction?

A. It *hastens* the apparent *rising* of the Sun and other heavenly bodies, and *delays* their apparent *setting*, beyond the true time; thus *increasing* the duration of daylight.

Q. Why do the Sun and Moon look OVAL, instead of ROUND, when near the horizon?

A. This is owing to *refraction:* they do not appear round, because the lower limb or edge is *raised* by atmospheric refraction.

Whatever increases the density of the atmosphere augments its refractive power. (*See Note* 44.)

"O'er yonder eastern hill the twilight pale
Walks forth from darkness."—AKENSIDE.

Q. What is TWILIGHT, or the CREPUSCULUM?

A. The *faint light* which may be perceived a short time *before* sunrise and *after* sunset.

Q. Do we see only by the DIRECT LIGHT of a luminous object?

A. No: if *any portion* of the direct rays from a luminous body are intercepted in their course, and *thrown back* upon us, it serves as a means of illumination.

Q. How can a luminous body ENLIGHTEN us, if the direct rays from it CANNOT REACH us?

A. The atmosphere sends us a portion of the light from the luminous body, not by direct transmission, but by the *refraction* of its rays, and the *reflection* of them upon the vapors and solid particles which float in the air.

Q. Why is a SINGLE SUNBEAM let through the crevice of a close shutter sufficient to prevent entire darkness in an apartment?

A. Because the atmosphere has the property of *reflecting* a portion of its light.

Q. What are those LINES of LIGHT sometimes seen in the atmosphere, vulgarly called "the Sun drawing water?"

A. Those lines of light are the *direct rays* of the Sun shining through some broken clouds; but the light from them is *reflected* by the atmosphere.

Q. Do the Sun's rays FALL upon the ATMOSPHERE after he has sunk below the horizon?

A. They do; and the light is *refracted* and *reflected* by the atmosphere, and thrown upon the Earth, producing *twilight.*

Q. How LONG does twilight usually CONTINUE?

A. Its duration depends very much upon the state of the atmosphere; but, under ordinary circumstances, twilight ends in the evening and commences in the morning when the Sun is eighteen degrees below the horizon.

> "The tender twilight with a crimson cheek
> Leans on the breast of Eve."

Q. What happens in HIGH LATITUDES, when, for a portion of the year, the Sun never sinks more than 18° below the horizon?

A. To those places twilight *never ends* from *sunset* to *sunrise;* that is, there is no *night.*

DIVISION IV.—ABERRATION.

Q. What is meant by ABERRATION?

A. The difference in the apparent motion of the fixed stars, caused by the *velocity of the Earth* combined with the *velocity of light.*

Q. Is light propagated INSTANTANEOUSLY from a luminous body?

A. No; light requires *time* to travel from the luminous body which emanates it.

Q. Does light require TIME to travel from the heavenly bodies to the Earth?

A. Yes; light travels at the rate of *one hundred and ninety-two thousand miles* in a *second* of time; therefore we see the heavenly bodies by rays which left them some time before.

Q. How was it DISCOVERED that light requires time to travel through space? for if a candle be lighted in an apartment, no perceptible time is required to illuminate every part of it.

A. It was discovered by a *comparison* of observations made on the *eclipses of Jupiter's satellites.*

The distance across an apartment is too small to admit of the measurement of the time required by the light to travel from one extremity of it to the other. The time which light requires to travel even a *mile* is too small to be appreciable by any means of measurement which we possess; but it is measurable at the distance of Jupiter.

Q. Who DISCOVERED the progressive motion of light?

A. *Roemer*, a Danish astronomer, in the year 1667.

Q. How was Roemer LED to this conclusion?

A. He found that when Jupiter was *opposite* to the Sun, or in that part of his orbit *nearest* to the Earth, the eclipses of his first satellite occurred *sooner* by *sixteen minutes and twenty-six seconds*, than when he was in *opposition*, or in that part of his orbit *farthest* from the Earth.

Q. What did he INFER from this discovery?

A. He concluded that the light reflected by Jupiter required sixteen minutes and twenty-six seconds to travel over the diameter of the Earth's orbit; therefore it would require *eight minutes and thirteen seconds* to travel *half* that distance, or from the *Sun to the Earth.*

This theory at first met with violent opposition, but it was afterwards confirmed.

Q. What OTHER DISCOVERY confirmed the theory of the successive transmission of light?

A. The discovery of the *aberration of light*, by Dr. Bradley, in 1727.

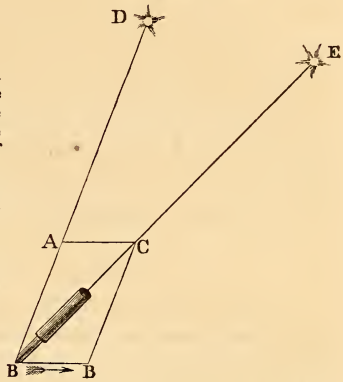
Q. What is the GENERAL EFFECT of aberration upon the appearance of the stars?

A. It causes each star to describe (in appearance only) a very *small ellipse* in the course of the year; the central point of the ellipse being the place the star would seem to occupy if our Earth were at rest.

Q. Why does aberration cause the APPARENT places of the stars to DIFFER from their TRUE ones?

A. Owing to the *motion* of the Earth in her orbit, the rays emanating from a star appear to reach us from a *different direction* to what they would were the Earth at rest.

Fig. 113.



Let B B be a part of the Earth's orbit, and D the place of a star. Now, in order to see the star, the telescope must be inclined in the direction B E; for if it were pointed to the true place of the star D, the rays of light, instead of falling through the tube to the spectator's eye, would strike against its sides. But as the Earth moves in the direction denoted by the arrow, the rays of light from D will appear to come from the point E. The angle D B E, contained between the axis of the telescope and a line drawn to the true place of the star, is its aberration.

Q. Suppose, then, we wish to observe a star; do we point the tube of the telescope to the star's TRUE place?

A. We do *not;* but *incline* it a *little*, so as to admit the ray of light from the star to the observer's eye, without *striking* against the *side* of the tube.

M. Clairaut, in the Memoirs of the Academy of Sciences for the year 1746, illustrates the effects of aberration in a familiar manner, thus: Suppose drops of rain, blown by the wind, to fall rapidly one after the other, and a person walk out, holding up a very narrow tube: it is evident that the tube must have a certain inclination, in order that a drop which enters at the top may fall freely through the axis of the tube without touching its sides; which inclination must be more or less, according to the velocity of the drops in respect to that of the tube. The angle made by the direction of the tube, and falling drops, is the aberration arising from the combination of those two motions.

Q. When is aberration at its MAXIMUM?

A. When a ray of light is *perpendicular* to the direction of the *Earth's motion;* but when it is *parallel* to the Earth's motion, aberration vanishes altogether.

Q. The fixed stars are at rest, or nearly so, with respect to the Earth, but the planets and comets are constantly changing their positions: are they, therefore, SIMILARLY AFFECTED by aberration?

A. There is a distinction between the aberration of the fixed stars and what is termed the aberration of *planets and comets;* for the moment a ray from a *moving* body reaches the Earth, the true position of that body is changed by its actual motion in its orbit.

Q. In what DIRECTION do objects always appear?

A. In the direction of the *rays* which *render them visible.*

Q. Are celestial objects always SITUATED in the DIRECTION of the rays which proceed from them?

A. They are *not;* but they would be if light were *propagated instantaneously.*

Q. How is the TRUE PLACE of a moving body to be found?

A. The distances of all the planets are known to us; and as we

also know the rate at which light would require to travel from them to us, it is only necessary to find how far the Earth has moved in the time, to determine the effect of the aberration, and consequently to discover the true place of the body.

Q. Do we ever see the Sun in his TRUE PLACE in the ecliptic?

A. No; for light requires 8′ 13″ to travel from the Sun to the Earth, and in this interval the Earth has moved over an arc of 20″·5, so that the Sun will appear 20″·5 *behind* his true place in the ecliptic. (*See Note* 45.)

DIVISION V.—PROPER MOTION.

Q. What is meant by PROPER MOTION?

A. An apparent motion of the fixed stars in *certain determinate directions* in the heavens.

Q. What is the CAUSE of the proper motion of the stars?

A. Two causes have been assigned: one is, that each star *may* have a *motion* to the *observed amount;* the other, that the solar system *may* have a *motion* in a *contrary direction* to the apparent motion of the stars.

Q. Are these motions of our Sun or the stars CERTAINLY KNOWN?

A. The proper motions of many of the stars are *known*, and it is believed that our solar system has a motion in space round some unknown centre. (*See Note* 46.)

It would require centuries of observations to solve this highly interesting problem, and to find the elements of the grand orbit of the solar system.

Q. Do any of the stars appear to have a more RAPID motion than others?

A. Yes; some few have attracted the attention of astronomers from their rapid motion, as compared with the rest. A star of the sixth magnitude, in the constellation Cygnus, numbered 61 in the catalogue, is moving at the rate of *more than five seconds of arc* annually.

Q. What, then, is the probable VELOCITY of the star 61 Cygni?

A. According to the observation of its angular movement, its velocity cannot be less than about *six thousand millions of miles in an hour!!*

Q. Have not these inconceivable velocities CHANGED the APPARENT PLACES of the stars very considerably?

A. Since the commencement of the Christian era, the apparent place of 61 Cygni has only undergone a change of about $2\frac{1}{2}°$.

Q. How can this apparent small change of place be ACCOUNTED FOR?

A. The star is situated at such an *immense distance* from us, that although its motion is very great, it is *imperceptible* to us, unless we compare it with former observations.

To a person standing on an eminence on the sea-coast, a ship in the horizon or offing, moving at the rate of ten miles an hour, would appear stationary. Its motion would

only be perceptible after comparing its situation with the point it occupied at some portion of time previous. As the nearest fixed stars are situated at such immense distances from us, it requires many years of observation to detect any motion in them.

Q. In travelling through a forest, what APPARENT CHANGES take place in the positions of the trees?

A. Those situated in the direction of our path seem to *diverge* or *spread asunder*, while those which we are leaving behind us appear to be *contracting* or *approaching each other.*

Q. What INDUCED Sir William Herschel to embrace the opinion of our solar system having a proper motion in space?

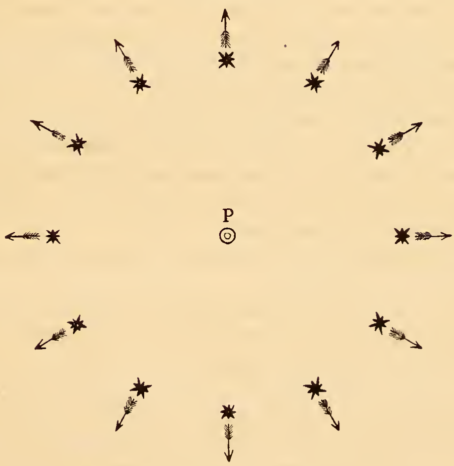
A. He observed a decided tendency in the stars in one part of the heavens to *diverge* or *separate*, and those in the opposite direction to *draw together* or *contract.*

Q. What did he INFER from this appearance?

A. He inferred from this that we are *approaching* the stars which appear to *diverge*, and *receding* from those which appear to draw closer together.

The accompanying figure represents the effects of the Sun's motion in space. Let P be the point towards which we are approaching, and it will be perceived by the indication of the arrows that the stars are separating or diverging in the quarter towards which we are advancing.

Fig. 114.



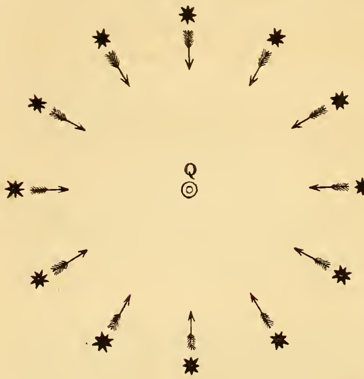
Q. What APPEARANCE does a cluster of objects present, when receding from it?

A. The individuals forming the cluster appear to be more *crowded together* the farther we recede from them.

Q. Does the appearance of CROWDING or converging occur among the stars?

A. It does; those stars in the *opposite part* of the heavens from which they seem to diverge, appear *closer together.*

Fig. 115.



Let Q (*fig.* 115) be the point opposite to P, *fig.* 114. It will be seen by the direction of the arrows that the stars are converging or crowding together.

DIVISION VI.—PARALLAX.

Q. What is PARALLAX?

A. Parallax is that *arc* of the heavens intercepted between the *true* and *apparent* place of a celestial body.

Q. What is the parallax of the Sun or Moon?

A. The parallax of the Sun, Moon, or a planet, is the measure of the Earth's radius or semi-diameter, as seen from that body.

Q. Is the calculation of parallax of any USE in Astronomy?

A. The computation of parallax affords the means of ascertaining the *distances* of the heavenly bodies.

Q. How can the distance of the Moon be ASCERTAINED?

A. The distance of the Moon may be obtained by noting the instant of her *touching the horizon*, and by drawing imaginary lines from her centre, one to the centre of the Earth, and the other to the eye of the spectator.

Q. How can these lines, the one drawn to the centre of the Earth, and the other to the spectator, be measured?

A. The two imaginary lines, together with a line drawn from the spectator to the centre of the Earth, would form a *right-angled triangle*, provided the Moon was in the horizon at the time of observation; and as the distance from the surface to the centre of the Earth is known, as well as all the angles, the distance of the Moon from the centre of the Earth may easily be computed.

Q. Where should a body be SITUATED for the effect of parallax to be at the maximum?

A. The effect of parallax is always greatest when the body is situated in the *horizon.*

Q. When a body is situated in the horizon, what is the parallax CALLED?

A. It is called the *horizontal parallax.*

Q. Have the FIXED STARS any parallax?

A *Very few* of the fixed stars have any sensible parallax.

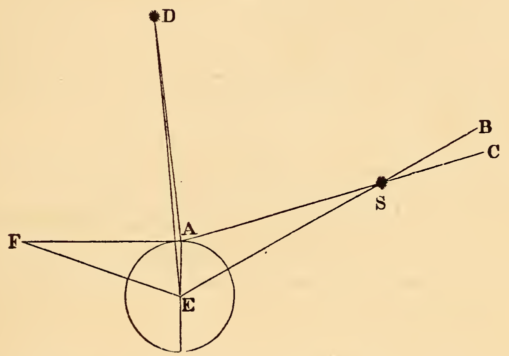
Q. Why have not the STARS any parallax, as well as the Sun, Moon, and planets?

A. Because the stars are at such *inconceivably immense distances* from us, that with but few exceptions, we have no means of ascertaining their parallax.

Q. Does the DISTANCE of a body have any effect on its parallax?

A. Undoubtedly; the nearer a body is to the Earth, the greater is its parallax.

Fig. 116.



Suppose, in *fig.* 116, A to be the station of an observer at any place on the surface of our globe, and E its centre. A planet at S will appear to the spectator at A, in the direction A C, while if it could be viewed from the centre of the Earth, its direction would be in the line E B. It is therefore seen from A at a point in the heavens *below* its position in reference to E. The angles formed by the intersection of the lines A S and E S is called the *parallax* of the planet.

Q. What EFFECT does parallax produce upon the apparent places of the Sun, Moon, and planets?

A. Parallax causes the Sun, Moon, and planets to appear *nearer to the horizon;* that is, *below* the positions they would occupy if viewed from the Earth's centre.

Q. Which planet would have the GREATEST parallax, Venus or Uranus?

A. *Venus*, because she is *nearer* to the *Earth* than Uranus; and the nearer a body is to the Earth, the greater is its parallax.

If, in the above figure, (116,) the point S had been placed as near again to A as it is there given, the lines A S and E S would be much more inclined than they are now drawn; and, on the contrary, if S were removed to twice the distance from A that it is represented in the figure, the two lines would be less oblique to each other than they are now.

Q. Does the EFFECT of parallax upon the Sun, Moon, or a planet VARY according to its POSITION with respect to the observer?

A. Yes; if the body be in the horizon, the effect is greatest, and is then called the *horizontal parallax.* (*See Note* 47.)

If the Sun, Moon, or a planet be at F, (*fig.* 116,) which is the horizon of the observer at A, the parallax is the greatest, and is called the horizontal parallax, which is the measure of the Earth's semi-diameter A E, as seen from the body at F.

Q. If a body be situated in the ZENITH, has it any PARALLAX?

A. It has *not.*

If a body were situated *near* the zenith, as at D, (*fig.* 116,) the parallax would be very small, the lines A D and E D nearly coinciding with each other. A body situated in the zenith has no parallax.

Q. If a star be observed from two OPPOSITE POINTS of the Earth, would it exhibit no APPRECIABLE CHANGE of position?

A. A star exhibits no *perceptible change* of place from whatever part of the Earth it may be viewed.

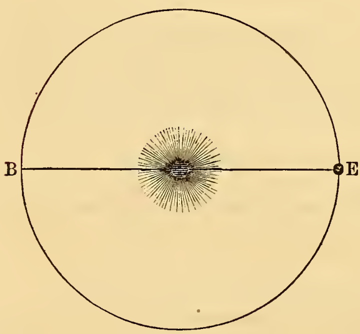
Q. How, then, has any parallax been DISCOVERED in the fixed stars, if the diameter of the Earth is TOO SMALL to subtend an angle at such immense distances?

A. Instead of using the Earth's diameter, of about eight thousand miles, as a measuring line, astronomers make use of the *diameter of the Earth's orbit,* which is about one hundred and ninety millions of miles.

Q. How is the diameter of the Earth's orbit KNOWN?

A. It is known that the Earth is situated about ninety-five millions of miles from the Sun; therefore, allowing the Sun to be placed in the centre of her orbit, the distance from one extremity of the orbit to the other would measure twice ninety-five millions, or, in round numbers, one hundred and ninety millions of miles.

Fig. 117.



The radius, which is the distance from the Sun to the Earth E, is ninety-five millions; consequently the whole diameter from E to B is one hundred and ninety millions. In the figure, the Sun is represented in the centre of a circular orbit; but the Earth's orbit is slightly elliptical, the Sun being situated in one of the foci of the ellipse.

Q. How can the EARTH'S ORBIT be used as a base line whereby to find the parallax?

A. If the place of a star be accurately observed on a given day,—the 1st of January, for instance,—and again in six months after, or on the 1st of July, its place be noted, and it be found that the diameter of the Earth's orbit subtends an angle, however minute, at that star, its distance could be computed as before stated.

Q. What is the ANGLE CALLED which is formed by two converging lines drawn from opposite points in the Earth's orbit to a given star?

A. The angle formed by two imaginary lines running from op-

posite points of the Earth's orbit to a star, is called the *parallactic angle.*

As regards most of the fixed stars, their distance from us is so immense, that although we view them in July and January from points one hundred and ninety millions of miles asunder, their apparent place is not changed; or, in other words, lines drawn from the extremities of the great base line of one hundred and ninety millions of miles to the star, would so nearly coincide, as to form no appreciable angle.

Q. What is the PARALLAX CALLED which is due to the yearly motion of the Earth round the Sun?

A. It is called the *annual parallax.*

CHAPTER II.

Distances of the Fixed Stars.

"How distant some of the nocturnal suns!
So distant, says the sage, 'twere not absurd
To doubt, if beams set out at Nature's birth,
Are yet arrived at this so foreign world;
Though nothing half so rapid as their flight"—YOUNG.

Q. Are the DISTANCES of any of the fixed stars accurately known?

A. But few of the stars have been found to have any *sensible parallax;* consequently, their distances are not *certainly known.*

Q. At what DISTANCE are the fixed stars supposed to be from us?

A. The nearest of the fixed stars is supposed to be about *twenty billions of miles* from us.

The ray of light by which we see the nearest of the fixed stars has been more than three years on its journey before it reaches our eye.

Q. Has the DISTANCE of any of the more remote stars been COMPUTED?

A. Yes; Sir William Herschel calculated that some of the stars require a period of *thirteen thousand years* for light to travel from them to us at the rate of 200,000 miles in a second. (*See Note* 48.)

Q. Have any other stars been discovered to have a PARALLAX? that is, have their DISTANCES been measured?

A. Yes; a star in the southern hemisphere, in the constellation Centaur, called *α* Centauri, is supposed to be the nearest fixed star. Its distance is calculated to be twenty billions of miles.

Q. How can such immense distances be MEASURED?

A. By observing their *different positions* when viewed from stations widely asunder.

Q. Does the same star appear to hold a DIFFERENT POSITION when viewed from opposite sides of the Earth?

A. It does *not.* The Earth's diameter of eight thousand miles is *too small* to afford sufficient base for ascertaining the distance of the fixed stars.

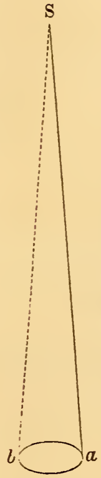
Q. How does a fixed star APPEAR when viewed from opposite sides of the Earth?

A. It seems to hold the *same position* exactly.

Q. From what two stations, MORE WIDELY asunder than the opposite sides of the Earth, can any fixed star be viewed?

A. The two stations from which a fixed star may be viewed, are the *opposite sides* of the Earth's *vast orbit.*

Fig 118.



Let S (*fig.* 118) represent a fixed star, and *a b* the orbit of the Earth. If the Earth is at the point *a* on the 1st of January, she will be at the point *b* on the 1st of July. The distance between the two stations is one hundred and ninety millions of miles. If any fixed star be observed on the 1st of January on the line *a* S, on the 1st of July the same star will appear in the line *b* S, if the star have any parallax.

Now, if instead of the star being drawn two inches from the Earth's orbit, let it be drawn at the distance of *ten miles,* preserving the orbit of the Earth of the same size as in the figure. It is evident that the diameter *a b* would be immeasurable from a point situated at that immense distance.

Q. How is it possible to ascertain whether a star seems to hold exactly the SAME POSITION in the heavens before and after an interval of six months?

A. Some small star is selected near to the one whose parallax we wish to observe, and the *distance* of the object of observation from the small star is correctly ascertained at the *two periods.*

Q. How is the distance separating the two stars DETERMINED?

A. This distance is determined by means of an instrument called a *micrometer.*

The micrometer consists of parallel threads, which can be moved, by means of a screw, in such a manner that the threads may be brought close together or separated. The observer adjusts his micrometer so as to bring one of these threads over each star; then the number of turns of the screw is noted which is required to make the two threads meet. The screw for this purpose is very delicately cut. This mode of estimation assumes that the smaller of the two stars is so much more remote than its companion, as to have its apparent position affected much less by the observer's change of place.

Q. What is this difference of position a star seems to hold, accordingly as it is seen from one or the other side of the Earth's orbit, CALLED?

A. This difference of apparent position of a star in the heavens, as seen from opposite sides of the Earth's orbit, is called its *annual parallax.*

Q. How is this amount of parallax MEASURED?

A. It is measured by what is termed the *parallactic angle.*

The angle formed between the two converging lines drawn from the star S, (*fig.* 118,) one to *a*, and the other to *b*, on the Earth's orbit. The angle S is the parallactic angle for the change of place from *a* to *b*.

Q. Have MANY of the fixed stars been found within a measurable distance?

A. But *few* have been ascertained to be *near enough* to our system to admit of their distances being measured.

According to the computations of Sir William Herschel, there are stars so distant, that light, which travels at the rate of 200,000 miles in a second, would require 13,000 years to travel from those stars to our Earth. Hence it follows, that if such a star were to be at this moment extinguished, the inhabitants of the Earth would continue to see the star for 13,000 years to come!

Such contemplations are sufficient to overwhelm us. The question naturally arises, For what purpose were all these luminaries created? "Surely," says Sir William Herschel, "not to illumine *our* nights, which an additional moon of the thousandth part the size of our own would do much better; nor to sparkle as a pageant, void of meaning and reality, and bewilder us among vain conjectures. Useful, it is true, they are to man as points of exact and permanent reference; but he must have studied astronomy to little purpose who can suppose man to be the only object of his Creator's care, or who does not see, in the vast and wonderful apparatus around us, provision for other races of animated beings."

"Seest thou those orbs that numerous roll above?
Those lamps that nightly greet thy visual powers
Are each a bright capacious sun like ours.
The telescopic tube will still descry
Myriads behind, that 'scape the naked eye;
And farther on, a new discovery trace
Through the deep regions of encompassed space.
If each bright star so many suns are found,
With planetary systems circled round,
What vast infinitude of worlds may grace.
What beings people the stupendous space!!
Whatever race possess the ethereal plain,
What orbs they people, or what ranks maintain,
Though the deep secret Heaven conceal below,
One truth of universal scope we know:—
Our nobler part, the same ethereal mind,
Relates our Earth to all their reasoning kind;
One Deity, one sole-creating Cause,
Our active care and joint devotion draws."

CHAPTER III.

The Milky Way.

"Throughout the Galaxy's extended line,
Unnumbered orbs in gay confusion shine
Where every star that gilds the gloom of night,
With the faint trembling of a distant light,
Perhaps illumes some system of its own
With the strong influence of a radiant Sun."—ELIZABETH CARTER.

Q. Are there any stars MORE REMOTE than those which are distinguishable by the naked eye?

A. There are *innumerable* stars which are *not visible* to the naked eye.

Q. How is it known that there are stars which are BEYOND THE REACH of unassisted vision?

A. As soon as the telescope is employed, numerous stars appear which before were *invisible.*

Q. How many ADDITIONAL STARS does the telescope reveal?

A. Some parts of the heavens are found to be studded with a *countless host of stars.*

Q. How MANY STARS may be seen at one time in the telescope? that is, in one single field of view?

A. As many as *five hundred* have been seen in a single field of a telescope.

Struve estimates that at least twenty millions of stars may be visible throughout the heavens in a good telescope. Sir William Herschel once counted *fifty thousand* stars in a space fifteen degrees long and two degrees wide.

Q. Is an EQUAL NUMBER of telescopic stars visible in the different regions of the heavens?

A. By no means: in some directions *hundreds* are seen in the field of the telescope; whereas but *few* appear if the telescope be turned to other portions of the heavens.

Q. Can any ONE SECTION of the heavens be designated as containing an unusual number of stars?

A. There is *one great circle* entirely surrounding the heavens, in which telescopic stars are very densely crowded together.

Q. What is that great circle of stars CALLED?

A. It is called the *Milky Way.*

It is also known by the names of the *Galaxy* and *Via Lactea.*

Q. What is the APPEARANCE of the Milky Way?

A. The Milky Way, as seen on dark nights by the naked eye, appears like an irregular stream of *faint, cloudy light.*

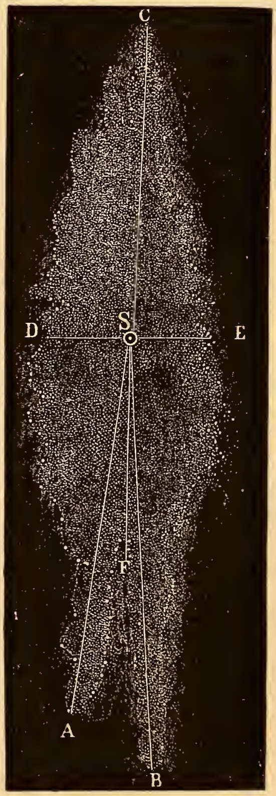
"A broad and ample road, whose dust is gold
And pavement stars, as stars to thee appear,
Seen in the Galaxy—that Milky Way
Which nightly, as a circling zone, thou seest
Powdered with stars."—MILTON.

Q. Does the Milky Way form a CIRCLE in the heavens?

A. It does: beginning not far from the north pole, and running south, it divides into *two branches* near the ecliptic, after which they *reunite*, pass near the south pole, and curve towards the north, extending in that direction to the place of beginning.

Its course may easily be traced on a celestial globe or map.

Fig. 119.



Q. What is this MILKY LIGHT supposed to be?

A. It really emanates from *thousands of stars* which are too distant to be seen, but whose united light has this cloudy appearance.

Q. Why do we see the greatest abundance of telescopic stars along this CIRCULAR TRACT of the heavens called the Milky Way?

A. Because the group of stars in which our Sun is placed extends *at a greater distance* round us in that ring.

Q. What is the supposed FORM of the Milky Way?

A. It is supposed to be in the form of a thin layer or stratum, comprised between two plane surfaces parallel and near to each other, but prolonged to immense distances in every direction.

Sir John Herschel is of opinion that the Milky Way is *not* a stratum, but *an annulus*, or ring.

Q. Where is our Sun SITUATED with regard to the stratum called the Milky Way?

A. Our Sun is supposed to be one of the *stars composing the Milky Way*, and to occupy a point very near the *centre of it.*

In *fig.* 119, the Galaxy or Milky Way is represented according to the theory of Sir William Herschel. S represents the Sun in the centre. It will appear plain that a telescope pointed in the direction S A, S B, or S C, will reveal more stars than when pointed in the direction S D, S E, or S F, which accounts for some portions of the heavens being much more closely studded with stars than others. (*See Note* 49.)

"How is night's sable mantle labored o'er!
How richly wrought with attributes divine!
What wisdom shines! what love! this midnight pomp,
This gorgeous arch with golden worlds inlaid,
Built with Divine Ambition."—YOUNG.

CHAPTER IV.

Magnitude of the Stars.

Q. When the telescope is directed to a star, is the SAME EFFECT produced as when it is turned to a planet?

A. It is *not*. Generally speaking, the planets present a *circular disc*, whereas the stars appear like *brilliant points*.

Q. Is any OTHER DIFFERENCE observable between stars and planets when viewed through a telescope?

A. Yes. The telescope will *magnify* the discs of the planets, making them appear many times larger than when viewed with the naked eye; but instead of magnifying the diameters of stars, it makes them appear *smaller*, but *much brighter*.

Q. How can the telescope which MAGNIFIES the planets make the fixed stars appear SMALLER?

A. When we look at a star there is an *optical illusion* produced, which makes it appear as if surrounded by rays; the telescope *divests* it of this *illusive radiation*, and presents it to the eye as merely a *brilliant point*.

Q. Would telescopes of HIGHER magnifying power make a star look larger than a point?

A. No; with the *highest* magnifying powers the stars have *no apparent magnitude*.

Q. Have we ANY OTHER proofs that the stars have no sensible discs?

A. Yes; when the Moon passes between us and a star, producing an occultation, the star is *instantaneously* hidden by the Moon's disc.

Q. In case of an occultation by the Moon, what EFFECT would be produced if the stars had apparent diameters?

A. The edge of the Moon would slowly cover them; instead of which they always *disappear instantaneously*, preserving all their lustre until the moment of contact with the edge of the Moon.

Q. If, then, all the fixed stars are without perceptible magnitudes, how can any idea be formed of their DIMENSIONS?

A. An idea of their magnitudes is formed by a *measurement* of their *brilliancy*.

Q. How is the comparative brilliancy of the stars MEASURED?

A. By means of an instrument called a *photometer*.

A photometer designates the comparative brilliancy of any two luminous bodies, as that of a common candle and a gas-light, or of a candle and the noonday sun.

Q. How much NEARER to us would a telescope magnifying one hundred times bring a celestial body?

A. It would make a celestial body appear *one hundred times* nearer.

At the distance of the nearest fixed star, the whole orbit of our Earth, which is one hundred and ninety millions of miles in diameter, would appear but as a point.

Q. Has any comparison ever been instituted between the LIGHT of the SUN and any of the fixed STARS?

A. Yes. By means of the photometer it has been found that the light of Sirius, the brightest fixed star, is *twenty thousand million times* less than the light of our Sun.

Q. How FAR from us should our Sun be removed to appear no larger than the star Sirius?

A. It should be removed *one hundred and fifty thousand times* farther off.

In speaking of Sirius, the poet says—

"'Tis strongly credited this owns a light
And runs a course not than the Sun's less bright;
But that removed from sight so great a way,
It seems to cast a dim and weaker ray."—SIR EDWARD SHERBURNE.

Q. Is Sirius one hundred and fifty thousand times MORE DISTANT than our Sun?

A. Sirius is supposed to be at the least *six hundred thousand times* the distance of the Earth from the Sun.

Q. What, then, is the estimated SIZE of the sphere of the star Sirius?

A. It is conclusively proved that it is at least equal in magnitude to *fourteen* of our suns.

Dr. Wollaston, who made this estimate of the magnitude of Sirius, was not aware of the immense distance of that star from our system. Since that time, by observations made by Professor Bessel, it is proved that Sirius must be at least six hundred thousand times farther from us than our Sun, which would be at a distance beyond the power of human conception. If a railway car were to travel night and day at the rate of twenty miles an hour, it would require more than three hundred millions of years to accomplish the journey!

"Hail, mighty Sirius, monarch of the suns!
May we in this poor planet speak with thee?
Say, art thou nearer to His throne, whose nod
Doth govern all things?—Hast thou heard
One whisper through the open gate of heaven,
When the pale stars shall fall, and yon blue vault
Be as a shrivelled scroll?"—SIGOURNEY.

Q. How does a bright star like Sirius appear through a POWERFUL TELESCOPE?

A. When directed to the region of the heavens near the star, the light is so strong that it has the appearance of *sunrise;* and when the star is in the field of vision, the splendor is so great as to require a *colored glass* to *protect* the *eye.*

CHAPTER V.

Appearance of the Stars.

"There they stand,
Shining in order, like a living hymn
Written in light."—N. P. WILLIS.

Q. When the stars are examined through the telescope, have they the SAME APPEARANCE as when viewed by the naked eye?

A. They *have not;* when viewed through the telescope, they appear much more brilliant, and sometimes exhibit *different colors*, such as yellow, orange, red, green, &c.

It is supposed that the color of Sirius, or the Dog star, has changed since it was first observed by astronomers. Mr. Barker considers that it has changed from *red* to *white* (its present color) in the lapse of ages, and quotes Aratus, Cicero, Virgil, Ovid, Seneca, Horace, and Ptolemy to sustain him.

Q. Does the telescope reveal any other PECULIARITIES with regard to the fixed stars?

A. It shows some stars to be *variable and periodic*, others to be only *temporary*, some *compound*, and others arranged in *clusters* and *nebulæ.*

SECTION I.

Variable and Periodic Stars.

"That man who has never looked up, with serious attention, to the motions and arrangements of the heavenly orbs, must be inspired with but a slender degree of reverence for the Almighty Creator, and devoid of taste for enjoying the beautiful and the sublime."—*Dr. Dick.*

Q. Do all the fixed stars shine with the SAME DEGREE of BRILLIANCY?

A. No; many of the stars are known to *vanish* and *reappear* at regular intervals.

Q. What are those stars DENOMINATED which vanish and reappear periodically?

A. They are called *variable* or *periodic* stars.

Q. Do all the variable stars DECREASE in brilliancy till they DISAPPEAR altogether, and then return again to view?

A. No; some of the variable stars shining with the brilliancy of stars of the *second* or *third magnitude*, fade away until they appear of the *fifth* or *sixth*, and then increase in brightness again till they attain their maximum splendor.

Q. Do some become entirely INVISIBLE, and then APPEAR again?

A. Yes; some decrease in brilliancy till they become so faint as to be *invisible* with the best telescopes, after which they *appear again* with their former brightness.

Q. Which is the most REMARKABLE periodic star?

A. A star in the neck of the Whale, known by astronomers as *Mira*, or *o* (*Omikron*) *Ceti;* it decreases from a star of the second magnitude until it becomes invisible, and then returns to its former brightness.

Q. How LONG is the star Mira in passing through these variations of brilliancy?

A. It passes through these variations in about *three hundred and thirty-one days.*

Q. Are there any OTHER remarkable variable stars?

A. There is a very remarkable star called *Algol*, in the constellation *Caput Medusæ.*

The Constellation Caput Medusæ is generally united with the constellation Perseus. The astronomical designation of Algol is β (Beta) Persei.

Q. How does the star Algol VARY?

A. It varies from a star of the *second magnitude* or *brilliancy*, to the *fourth* magnitude.

Q. How LONG a PERIOD does Algol require to perform these variations?

A. Algol performs these variations in a little less than *three days.*

The period of this star is gradually diminishing at the rate of about the tenth of a second in a year. Its period is now about 2*d.* 20*h.* 48*m.* 53·37*s.*

δ (Delta) Cephei, β (Beta) Lyra, and some others, are known to be variable stars, as their periods have been estimated. But there are as many as fifty others whose degrees of variation and period are not determined with any degree of accuracy.

Q. What is the periodic variation of the light of the stars supposed to INDICATE?

A. It is supposed to indicate either that these stars *revolve* on their *axes*, or that large opaque bodies *revolve around* them.

Q. How can the variation of light be attributed to their REVOLUTION on their axes?

A. If luminous globes having opposite hemispheres of *unequal degrees* of *brilliancy* revolve upon their axes, the light and dark hemispheres must be *periodically* turned *towards* the Earth.

Q. How could large opaque bodies revolving around them make their light VARIABLE?

A. If large opaque bodies, in the process of revolution round luminous globes, come *between* those luminous globes and the observer's eye at certain fixed intervals, some part of the light emitted from those globes must be *periodically shut from our sight*, or in other words, the luminous body must be *eclipsed.*

SECTION II.

Temporary Stars.

"Oh! who can lift above a careless look,
  While such bright scenes as these his thoughts engage,
And doubt, while reading from so fair a book,
  That God's own finger traced the glowing page;
Or deem the radiance of yon blue expanse,
With all its starry hosts, the careless work of Chance!"

MRS. AMELIA B. WELBY.

Q. Have any CHANGES ever been observed in the fixed stars?

A. Yes; some stars have entirely *disappeared*, while new ones are sometimes found which *never were seen before.*

Q. How can this disappearance of known stars and appearance of new ones be ACCOUNTED for?

A. Astronomers do not pretend to give any reason for it, the fact being founded entirely on observation. Some suppose it to be owing to *dark orbs* revolving round these luminous bodies; but this is only conjecture.

"A million torches lighted by Thy hand
  Wander unwearied through the blue abyss,
They own Thy power, accomplish Thy command,
  All gay with life, all eloquent with bliss.
What shall we call them? Piles of crystal light—
  A glorious company of golden streams—
Lamps of celestial ether burning bright—
  Suns lighting other systems with their joyous beams?
But God, to these, is as the noon to night."

Q. Have new stars appeared OFTEN in the heavens?

A. Yes, *frequently.* On one occasion, about A. D. 389, a new star shone out suddenly in the constellation Aquila, which was as bright as the planet Venus.

This star only remained visible three weeks, and then disappeared entirely.

Q. How is it KNOWN when new stars appear?

A. There are *catalogues* of the principal stars, so that by consulting these, new stars are frequently detected.

The appearance of a new star, B. C. 125, prompted Hipparchus to form a catalogue of all the principal stars, which was the first ever made.

Q. Do these new stars appear with unusual BRILLIANCY?

A. *Not always;* but in 1572, Tycho Brahé, returning home one evening, saw a crowd of country people gazing at a star as bright as Sirius, which was not visible half an hour before.

This star increased in brilliancy till it surpassed Jupiter in splendor. (*See Note* 50.)

Q. Are any of these temporary stars suspected of appearing PERIODICALLY?

A. Yes; the star of 1572, mentioned by Tycho Brahé, it is sup posed *might* have been the same as the bright star which appeared in the year 1264; and both these are also suspected as being identical with one which was seen in 945.

If the star of the year 945, that of 1264, and the star of 1572 could be proved to be one and the same, it could not be ranked among the temporary stars, but should more properly be classed as a variable star.

Q. Can it be fully PROVED that the stars which have appeared once, and then have vanished, will ever be SEEN AGAIN?

A. No; it would require centuries of close observation to acquire any just conception of the motions of bodies so distant and so vast.

Many of the stars of the old catalogues are now missing, but some of these may have been the Asteroids, Uranus, or Neptune, in different parts of their respective orbits. Neptune, for instance, was recorded as a star, but has since proved to be a planet. No doubt some of the Asteroids and Uranus have also been catalogued as fixed stars.

SECTION III.

Compound Stars.

"Take the glass
And search the skies. The opening skies pour down
Upon your gaze thick showers of sparkling fire;
Stars, crowded, thronged, in regions so remote,
That their swift beams—the swiftest things that be—
Have travelled centuries on their flight to Earth.
Earth, Sun, and nearer constellations! what
Are ye amid this infinite extent
And multitude of God's most infinite works."—Henry Ware, Jr.

Q. How are the fixed stars SUPPORTED in space?

A. By the combined influence of *motion* and *attraction.*

The fixed stars are upheld in space by the operation of the same powers that serve to support the planets.

Q. How can it be KNOWN that the fixed stars are subjected to the influence of motion and attraction?

A. Stars have been discovered, by the aid of telescopes, which have a *revolution round each other* in elliptical orbits.

Q. What does the discovery of this elliptical motion of some stars round a common centre of gravity tend to PROVE?

A. It tends to prove that *gravitation is not peculiar* to our system of planets and satellites, but that systems of suns in the distant realms of space are also *subservient to its laws.*

DIVISION I.—DOUBLE STARS.

"One star differeth from another star in glory."

Q. When two adjacent stars are seen to revolve round a common centre of gravity, are they always of the same apparent BRILLIANCY?

A. No; the *smaller* or less brilliant one is seen to *revolve round* the larger star as its satellite.

Q. What are these stars which revolve round each other called?

A. They are called *double stars*, or *binary systems.*

Q. How do the two stars which revolve round each other APPEAR?

A. When visible to the naked eye, the two stars appear as *one.*

Some stars appear single, unless viewed through very powerful telescopes, when they may sometimes be separated into two or more.

Q. What is the FORM of the ORBITS of stars composing a binary system?

A. The orbits are often *very eccentric ellipses.*

Q. Are the periods in which any of the double stars complete their ELLIPTIC REVOLUTIONS known?

A. The periods of the revolutions of *many* of the double stars have been ascertained.

The stars of ζ (*Zeta*) Herculis complete their revolutions in about 35 years; those of γ (Gamma) Virginis, in 150 years; those of 61 Cygni, in about 500 years; and the double stars 65 Piscium require at least 3000 years to complete their revolutions.

Fig. 120.

Q. Have MANY of the fixed stars been found to be double?

A. Professor Struve has discovered more than *two thousand* double stars.

Q. Were they all visible to the NAKED EYE?

A. They were *not;* some can only be seen by means of the *best telescopes.*

Q. Do all the stars which appear double belong to the SAME SYSTEM? that is, have they a REVOLUTION round a common centre of gravity?

A. No; the double stars are divided into two kinds, the *optically* double and the *physically* double.

Q. What are the OPTICALLY double stars?

A. Those stars which are *not adjacent,* or united in one system, but are in fact very distant from each other, and appear as double, but are not really so. These are called *optically* double stars.

When two stars are situated nearly in a line with each other, the light emanating from them will follow the same line of direction. Consequently they have an appearance of contiguity, when in reality they are not adjacent, or even included in the same system, but far removed from each other. Thus, in *fig.* 120, the star *a* is nearer to the eye than the star *b*, but in the vast sphere of the heavens their distances appear the same; and in consequence of the light emanating from both *a* and *b* pursuing the same line of direction, they seem to be contiguous, as shown at the top of the engraving, when actually they are very remote from each other.

Q. What are PHYSICALLY double stars?

A. Physically double stars are those which compose one system, and are *united by mutual gravitation;* the smaller one revolving round the larger, or more properly, about their common centre of gravity.

Q. Are both stars in binary systems always of the SAME COLOR?

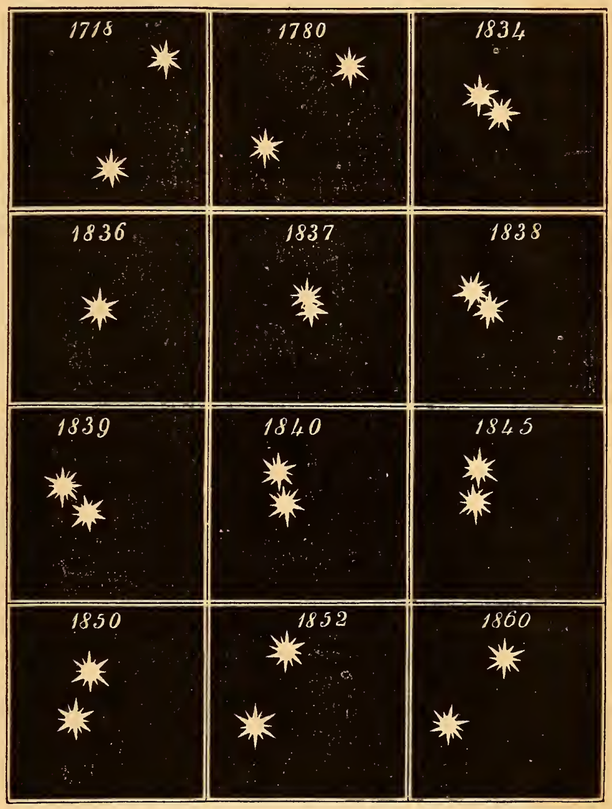
A. Not always; one star in a binary system is often of a *different* color from its companion.

When this is the case, the two stars have generally *complimentary colors;* that is, those contrasted colors which, when united, form white light. Orange and blue, for instance, or green and red, are complimentary colors.

The star γ (Gamma) Virginis is a very remarkable specimen of a binary system. One star is supposed to revolve about the other in a period of about 180 years. The positions of the two stars at different epochs may be seen by reference to *fig.* 121. In the year 1836 they are in a line with the Earth, and therefore appear as a single star, the one being hidden behind the other. They may be seen separating from 1837 until the year 1860, when they are shown to be again far asunder. These two stars are really always

at about the same distance from each other, but only appear single, owing to their situations with regard to us.

Fig. 121.



DIVISION II.—MULTIPLE STARS.

"And these are suns—vast central living fires—
Lords of dependent systems—kings of worlds
That wait as satellites upon their power,
And flourish in their smile. Awake, my soul,
And meditate the wonder! Countless suns
Blaze round thee, leading forth their countless worlds!
Worlds, in whose bosoms living things rejoice,
And drink the bliss of being from the fount
Of all-pervading Love!"

Q. Are there any systems of stars known to contain more than TWO members?

A. Yes; *many* systems contain *more than two stars.*

Q. What are these systems of stars containing MORE THAN TWO members called?

A. They are called *multiple stars.*

Q. Have any stars been seen having more than THREE members?

A. Yes; besides triple, there are also *quadruple* stars, and assemblages of even *five* or *six* stars.

The star σ (*Sigma*) Orionis may be resolved into a "double triple star," or two sets of stars containing three stars in each set. The star φ (Phi) Orionis, when seen through a powerful telescope, may be resolved into *six* component stars.

Q. Among the TRIPLE stars is there any instance known of a REVOLUTION round a CENTRE?

A. Yes; in the star ξ (Zeta) Cancri a powerful telescope shows *three* stars instead of a single one, *two* of which *revolve about the third.*

SECTION IV.

Clusters and Nebulae.

"To count their numbers were to count the sands
That ride in whirlwinds the parched Lybian air;
Or waves that, when the blustering north embroils
The Baltic, thunder on the German shore."

Q. Are the stars REGULARLY scattered over the firmament?

A. No: in some places they are *crowded* together; in others, *thinly dispersed.*

Q. What are these CROWDS of stars called?

A. They are called *clusters.*

Q. What does this clustering of the stars seem to INDICATE?

A. That members of the group or cluster have an attraction for each other, and a peculiar tendency to *group themselves together.*

Q. Are any clusters of stars visible to the NAKED EYE?

A. Yes; the well-known group called the *Pleiades* is a cluster.

This cluster, when examined with a good telescope, is found to consist of a great number of stars.

Q. What APPEARANCE has a cluster to the naked eye?

A. It usually presents a *white* or *hazy light.*

Q. What is the reason many clusters of stars appear like MILKY-WHITE SPOTS?

A. Because they are situated at such *immense distances* from us, that their united light appears only like a *faint cloud.*

Sir William Herschel calculated that a cluster consisting of five thousand stars, although *three hundred thousand* times more distant from us than Sirius, could be detected by the aid of a forty-feet telescope, as a milky spot of light. Lord Rosse's great telescope would, in all probability, catch a glimpse of them if removed to twice that distance.

Q. When viewed through a TELESCOPE, how do those distant clusters appear?

A. They then appear to be composed of countless numbers of stars congregated together.

In the constellation Hercules there is a *globular* cluster which is truly magnificent when seen through a powerful telescope. To the naked eye this cluster appears like a hazy object; but when viewed through a powerful instrument, its aspect is grand beyond description. The stars seem to be greatly condensed towards the centre, which gives forth a blaze of light.

Q. What is the usual FORM of clusters?

A. Some are *globular*, others *irregular* in their form.

Sir John Herschel says, "Among the most beautiful objects of this class is that which surrounds the star κ (Kappa) Crucis. It occupies a square area of about one minute and a quarter of arc, and consists of at least one hundred and ten stars, from the seventh magnitude downwards; eight of the more conspicuous of which are colored with various shades of red, green, and blue, so as to give to the whole the appearance of a rich piece of jewelry."

Q. Are those specks of cloudy light called CLUSTERS?

A. Yes; unless, indeed, the best telescopes *fail* to show them to be composed of *minute stars.*

Q. Has the NUMBER of stars in one of these faint clusters been COMPUTED?

A. Yes; many clusters which appear like cloudy specks have been computed to contain ten or twenty thousand stars when viewed through good telescopes.

If each of these stars be a sun, surrounded by a train of planets and comets, and each of these suns as far distant from each other as our Sun and the nearest fixed star, how vast must be that system, the combined light of whose thousands of suns appears only like a faint haze, and which has required thousands of years to reach us!

Q. What are these CLOUDY SPOTS of light called which the best telescopes cannot resolve into stars?

A. They are called *nebulæ.*

Nebula means a mist or cloud.

Q. Why are these specks of faint, cloudy light called NEBULÆ?

A. Because when the name was conferred on them, they were thought to be of a *misty or cloudy nature*, like the substance of some of the comets.

Q. How are the nebulæ DIVIDED?

A. First, into *nebulæ* properly so called, in which there is no *appearance of stars;* secondly, *planetary* nebulæ; thirdly, *stellar* nebulæ, or *nebulous stars.*

Q. Are there MANY nebulæ to be seen in the heavens?

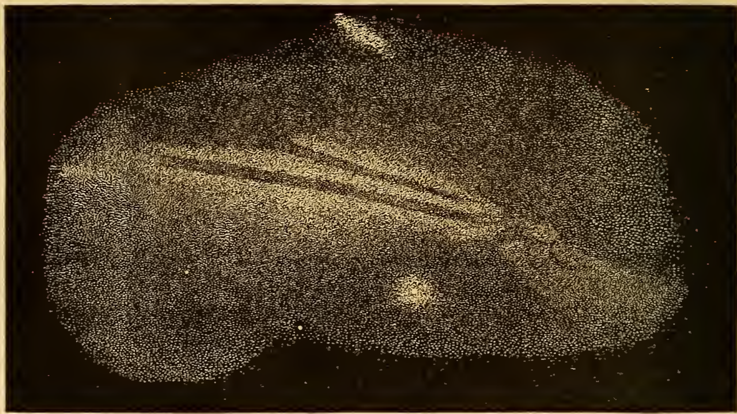
A. About *two thousand* nebulæ and clusters were observed by Sir William Herschel.

Their places were computed by Miss Caroline Herschel, the sister of Sir William, a lady eminent for her scientific knowledge and unwavering perseverance in astronomical discovery. She arranged these nebulæ and clusters in a catalogue in order of their right ascension.

Q. Do nebulæ assume any regular FORM?

A. They do *not;* some appear elliptical, some *annular*, some *globular*, &c.

Fig. 122.



The figure represents an elliptical nebulæ in the constellation Andromeda, as seen by Mr. George P. Bond, in the great refractor, Cambridge, Massachusetts.

Q. What are ANNULAR nebulæ?

A. Annular nebulæ are those which appear in the *form of a ring.*

Fig. 123.

The figure represents the annular nebula of the constellation Lyra, as seen through Lord Rosse's telescope. Through ordinary telescopes this nebula appears rather darker in the centre than at the edges, and looks like a hoop with gauze stretched over it. But the powerful telescopes of Lord Rosse resolve it into excessively minute stars, with a fringe of stars round the outer edge.

Q. Can GLOBULAR nebulæ be easily resolved into stars?

A. Yes; globular nebulæ are generally more *easily resolved* into stars than elliptical nebulæ.

Q. What are PLANETARY nebulæ?

A. They are nebulæ which have a close resemblance to *planets*, presenting round or oval discs, some of which are *sharply defined*, others a little hazy or softened at the edges.

Q. Have MANY planetary nebulæ been discovered?

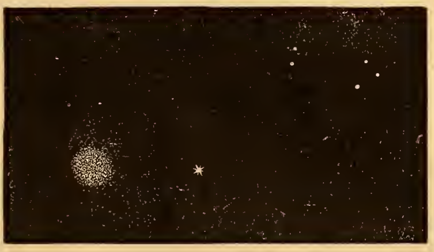
A. No; only about *twenty-five or thirty*, most of which are in the southern hemisphere.

Q. Do planetary nebulæ emit much LIGHT?

A. Yes; their light occasionally *rivals* that of the *planets.*

Planetary nebulæ are often attended by minute stars, which give the idea of accompanying satellites.

Fig. 124.



The above figure represents a planetary nebula, of a pale bluish white, situated in the constellation Argo. This nebula is immediately adjacent to some small stars, which are shown in the figure.

Q. Have the MAGNITUDES of planetary nebulæ been estimated?

A. Not with *any degree of certainty,* as their distances are unknown to us.

Sir John Herschel says, "Granting these objects to be equally distant from us with the stars, their real dimensions must be such as would fill, on the *lowest computation,* the whole orbit of Uranus;" that is, they must be at least *three thousand six hundred millions of miles in diameter.*

Q. What are STELLAR nebulæ?

A. These are nebulæ having a round or oval shape, *increasing in density towards the centre.*

Sometimes the condensation is so great as to give the appearance of a star with a blurred outline, or like a candle shining through horn.

DIVISION I.—DOUBLE NEBULÆ.

"Could we wing our way to the highest apparent star, we should then see other skies expanded, other suns that distribute their inexhaustible beams of day, other stars that gild the alternate night, and other, perhaps nobler, systems established—established in unknown profusion through the boundless regions of space. Nor do the dominions of the GREAT SOVEREIGN end there: even at the end of this vast tour, we find ourselves advanced no farther than the frontiers of creation, arrived only at the suburbs of the Great Jehovah's kingdom."—HERVEY.

Q. Are nebulæ, like the fixed stars, ever found DOUBLE?

A. Yes; double nebulæ *occasionally* occur, but they are not as common as double stars.

Q. Have double nebulæ any PHYSICAL CONNECTION with each other?

A. It is not certainly *known* that any relation subsists between them, yet the fact is strongly *suspected.*

Q. Have any of the double nebulæ been observed to have a revolution round a COMMON CENTRE?

A. They have *not,* with any *certainty;* yet it is believed they have a slight angular motion, which in the course of some hundreds

of years may be sufficient to afford data for the computation of their orbits.

Q. Are double nebulæ supposed to consist of stars?

A. Yes; no doubt the greater number are composed of *thousands of stars* each resembilng our Sun.

Sir John Herschel says, "Their stupendous scale, the multitude of individuals they involve, the perfect symmetry and regularity which many of them present, the utter disregard of complication in thus heaping together system upon system, and construction upon construction, leave us lost in wonder and admiration at the evidence they afford of infinite power and unfathomable design."

Fig. 125.

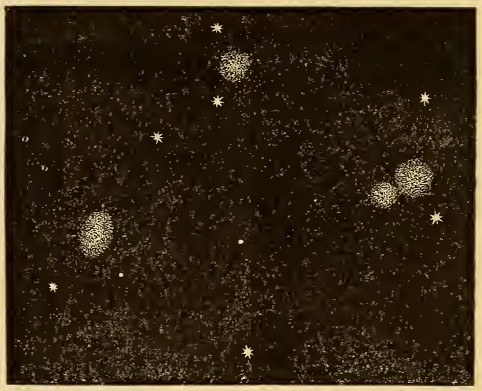


Fig. 125 represents a double nebula in the constellation Virgo, with two other nebulæ in the field of view at the same time. This double nebula may consist of stellar systems, each revolving round the other—each a universe.

"Stars teach, as well as shine."

DIVISION II.—NUBECULÆ, OR MAGELLANIC CLOUDS.

"I wonder as I gaze. That stream of light,
Undimmed, unquenched—just as I see it now—
Has issued from those dazzling points, through years
That go back far into eternity.
Exhaustless flood! forever spent, renewed
Forever!"

Q. What are the MAGELLANIC CLOUDS?

A. They are two *nebulous masses of light*, plainly visible to the naked eye.

Q. Where are the Magellanic clouds SITUATED?

A. In the *southern hemisphere*, near the south pole.

Q. What do they RESEMBLE?

A. They are like some of the brighter portions of the *Milky Way*.

Q. By what NAME are the Magellanic clouds known to astronomers?

A. They are called *Nubeculæ.* The larger cloud is called *Nubecula major*, and the smaller one, *Nubecula minor.*

Q. Of what are the Magellanic clouds supposed to CONSIST?

A. The Nubeculæ or Magellanic clouds are supposed to consist of an immense number of nebulæ; the greater Nubecula contains nearly *three hundred*, and the lesser one nearly *forty*, nebulæ.

The Nubecula major consists of upwards of 900 stars, nebulæ, and clusters, and Nubecula minor of more than 200. The Magellanic clouds, or, as they are generally termed by astronomers, Nubeculæ, were known to the Arabian astronomers as *El-Bakar*, or the *White Ox.* These two nebulous clouds of light are of an oval form; their brightness is such that the full moon obscures the light of the lesser, and renders the greater cloud barely visible.

The Nubeculæ never appear above the southern horizon of those who live farther north than from 16° to 20° north latitude.

CHAPTER VI.

Meteors.

Q. What are METEORS?

A. *Fiery* or *luminous bodies* occasionally seen moving rapidly through the atmosphere.

Q. Where have meteors their ORIGIN?

A. They are supposed to have their origin *beyond our atmosphere.*

They are considered as belonging to a nebulous body with which our Earth comes periodically in contact.*

Q. Of what do meteors CONSIST?

A. They are supposed to consist of *light combustible matter*, which moves with great velocity.

Q. Are they ever of LARGE dimensions?

A. Some have been seen which were *several thousand feet* in diameter.

Q. What EFFECT is produced when these bodies enter our atmosphere?

A. They *condense the air* before them so rapidly, that they elicit the heat which *sets them on fire.*

Q. By what NAMES are luminous meteors sometimes known?

A. They are sometimes, though very improperly, called *shooting stars.*

Q. From WHAT are these meteors supposed to EMANATE?

A. They are supposed to descend to us from some nebulous body far beyond the regions of our atmosphere.

---

* This theory of meteors and their origin is chiefly according to Professor Olmsted, who has devoted much attention to this subject.

Q. Do they ignite FAR above the surface of the Earth?

A. Yes; they sometimes take fire at the distance of *thirty miles* above our Earth.

Q. Do meteors appear very FREQUENTLY?

A. Yes; at all times of the year; but they are more frequently seen about the month of *November.*

Q. How do meteors make their APPEARANCE?

A. They usually appear *suddenly* in the clear, azure sky, and darting with great rapidity, are *extinguished* without noise, sometimes leaving a film of *smoky vapor* to indicate the spot they occupied.

In the twenty-ninth volume of the Transactions of the Royal Society of London, there is an interesting article from the pen of the great astronomer, Edmund Halley, containing an account of some meteors seen by him in the year 1718. A very remarkable one is cited by Halley, on the testimony of Sir Hans Sloane, who saw it while walking the streets of London. This meteor appeared in the evening, a few minutes after eight o'clock, the sky being clear, and the Moon shining brightly, near the meridian. Suddenly a great light appeared in the west, which he at first attributed to rockets or fireworks; but he was soon undeceived, for on casting his eyes towards the light, he saw a splendid meteor in the direction of the Pleiades, having a long luminous train or tail of a most dazzling brilliancy. It left behind it a track of a yellowish-red color, which seemed to sparkle. The splendor of this meteor was little inferior to that of the Sun; and so strong was the light, that within doors candles were of no use; and although the Moon shone brightly, her light was scarcely visible. In fact, for a few seconds, the light resembled that of day.

Q. What is the general DIRECTION of meteors?

A. They appear in all parts of the heavens, and dart in all possible directions; but the greatest number move from east to west.

Meteors sometimes fall to the Earth in showers of thousands, which emit so much light as to illuminate the heavens. A shower of this kind was seen in November, 1799; another in November, 1831; also in November, 1832, multitudes of shooting stars fell in the western part of Asia and southern part of Europe. But the most magnificent shower of meteors which has ever been known was that which fell during the night of November 12, 1833. This shower commenced at nine o'clock in the evening, and continued till the morning sun concealed them from view. It extended from Canada to the northern boundary of South America, and over a tract of nearly three thousand miles in width, its western limit extending to longitude 100° west from Greenwich.

SECTION I.

Meteorites or Aerolites.

Q. Do meteorites RESEMBLE meteors?

A. They frequently have the *same brilliancy* as meteors, and sometimes emit a much *brighter light.*

Q. Are meteorites attended with any NOISE?

A. Yes; they are sometimes attended with a *loud hissing noise*, and sometimes it resembles the *report* of a *cannon.*

Q. Are meteorites TANGIBLE substances?

A. *They are.*

Q. Do they ever FALL to the Earth?

A. Yes; and they are composed generally of a few metallic elements, as iron and nickel, &c.

Q. Do these metallic substances ever FALL to the Earth in large quantities?

A. They do. Sometimes they fall in *large masses*, and sometimes in *showers of stones.*

In the year 1620 a violent explosion was heard at a village in India, and at the same time a luminous body fell to the Earth. The officer of the district immediately repaired to the spot to examine the cause of the phenomenon. He employed some men to dig, and as they threw up the earth he found the heat increase very perceptibly, till finally they reached a lump of iron excessively hot. This curiosity was sent to court, and the king had it weighed in his presence. He then ordered it to be made into a sabre, a knife, and a dagger, for his own use. But the workmen found, after several trials, that the thing was impossible, as the metal was not malleable, but shivered under the hammer; they afterwards mixed with it a one-third part of common iron, when they were able to produce excellent blades. The historian of this king adds—"During his reign the Earth retained order and regularity; raw iron fell from lightning, which was, by his world-subduing authority, converted into a sabre, a knife, and a dagger."

Q. Do meteorites ever pass NEAR to the Earth without falling to its SURFACE?

A. Yes; sometimes they approach to within a *short distance* of the Earth without falling on its surface.

Mrs. Somerville mentions one which passed within twenty-five miles of our planet, and which was estimated to weigh about six hundred thousand tons, and to move with the velocity of twenty miles in a second. Only a small fragment of this immense mass reached the Earth.

Q. Why are meteorites supposed to be of FOREIGN ORIGIN?

A. Because they have *peculiar characteristics*, which belong to no native rocks or stones with which we are acquainted. (*See Note* 51.)

Q. Are there any OTHER reasons for supposing they have not their origin on our Earth?

A. The almost invariable *obliquity* of their descent, and the *explosion* accompanying their fall, show they are not of terrestrial origin.

Q. Have meteorites of LARGE SIZE ever fallen to the Earth?

A. Many weighing from *fifty* to a *hundred pounds* have fallen to the Earth, and in some instances the masses have been much larger.

Q. How, then, is the origin of meteorites ACCOUNTED for?

A. They are supposed to be *fragments* of some body or bodies which are revolving round the Sun, and become visible when they are inflamed by entering our atmosphere.

These bodies, which may exist by thousands in the vicinity of our globe, are supposed to revolve in orbits having a period corresponding to one or more revolutions of the Earth, which will account for our seeing more of them at certain seasons of the year. But all this is mere conjecture; nothing is yet certainly known with regard to these wonderful appearances.

SECTION II.

The Zodiacal Light.

Q. What is the ZODIACAL LIGHT?

A. A *conical-shaped light* which appears at certain seasons of the year just *after sunset*, or immediately *before sunrise*. The centre of the base of the cone is in a line with the centre of the Sun.

Q. What is the APPEARANCE of this light?

A. It resembles the light of the *Milky Way*.

Q. What is this light supposed to BE?

A. It is supposed to be a *nebulosity* around the Sun.

Q. If this be the case, how would our Sun appear to the STARS?

A. He would appear as the *nebulous stars* do to us.

Q. At what SEASONS of the year is the zodiacal light most plainly visible?

A. During twilight in northern latitudes, in the evenings of *March*, *April*, and *May;* and in the morning twilight of the months of *September*, *October*, and *November*.

Q. What is the MAGNITUDE of the zodiacal light?

A. It extends *beyond* the orbits of Mercury and Venus, and perhaps reaches even as far as our Earth; which would be equal to *ninety-five millions of miles* in length.

Sir John Herschel thinks it may possibly be the denser part of the ethereal medium, which, it is believed, is the substance which resists the motions of comets. He also supposes this nebulous envelope may be composed of the materials of the tails of millions of comets, which have been stripped of these appendages during their perihelion passage. Some have supposed this nebulous light to be the atmosphere of the Sun; but modern astronomers are of opinion that the existence of a gaseous envelope of such enormous dimensions could not be sustained according to the laws of dynamics.

Q. Is there any supposed RELATION between the zodiacal light and the meteoric showers?

A. Professor Olmsted, of Yale College, and Messrs. Arago and Biot, are of opinion that the substance composing the zodiacal light furnishes the materials which constitute the meteoric showers. (*See Note* 52.)

So little is definitely known in this department, that most of it is merely conjecture. All we can do is to state the facts, and give the opinions which the most learned astronomers have deduced from them.

"That which we know, is little; that which we know not, is immense."—*La Place.*

CHAPTER VII.

Constellations.

TO TEACHERS.—The configurations of the heavens are to the astronomer what the natural divisions of the Earth are to the geographer. To the student of geography, the natural divisions of the Earth, its oceans and continents, the situation of its poles, equator, and tropics, are the first steps towards a more thorough acquaintance with the science. In like manner, it is necessary that the student of astronomy should have a correct idea of the relative positions of the principal groups of stars, the places of the poles, equinoctial and ecliptic, else he would be as much at a loss as the traveller with-

out a landmark. It is desirable, therefore, that the following questions should be answered, without committing them to memory, but merely by the aid of the map or globe, in order that the student may become familiar with the constellations and their relative situations. The localities of those constellations of the southern hemisphere, which are never seen in the United States, should be learned, for the same reason that we study the geography of countries which we never expect to visit.

The following list of zodiacal constellations in their order, and of the northern and southern constellations alphabetically arranged, with their astronomical names and translations, are given below. Table XI., at the end of the volume, shows them in order of right ascension, with their declinations, &c.

ZODIACAL CONSTELLATIONS.

Name.	Translation.
Aries	Ram.
Taurus	Bull.
Gemini	Twins.
Cancer	Crab.
Leo	Lion.
Virgo	Virgin.
Libra	Balance
Scorpio	Scorpion.
Sagittarius	Archer.
Capricornus	Sea-goat.
Aquarius	Water-bearer.
Pisces	Fishes.

NORTHERN CONSTELLATIONS.

Name.	Translation.
Andromeda	Andromeda.
Antinous	Antinous.
Aquila	Eagle.
Auriga	Charioteer.
Bootes	Bear-driver.
Camelopardalus	Cameleopard.
Canes Venatici	Greyhounds.
Caput Medusa	Medusa's Head.
Cassiopeia	Cassiopeia.
Cepheus	Cepheus.
Cerberus	Three-headed Dog.
Coma Berenices	Berenice's Hair.
Cor Caroli	Charles's Heart.
Corona Borealis	Northern Crown.
Cygnus	Swan.
Delphinus	Dolphin.
Draco	Dragon.
Equuleus	Little Horse.
Hercules	Hercules.
Honores Frederici	Frederick's Glory.
Lacerta	Lizard.
Leo Minor	Lesser Lion.
Lyncis	Lynx.
Lyra	Lyre.
Mons Menalus	Menalus Mountain.
Musca Borealis	Northern Fly.
Ophiuchus	Serpent-bearer.
Pegasus	Flying Horse.
Perseus	Perseus.
Quadrans Muralis	Mural Quadrant.
Sagitta	Arrow.
Scutum Sobieski	Sobieski's Shield.
Serpens	Serpent.
Tarandus	Reindeer.
Taurus Poniatowski	Poniatowski's Bull.
Telescopium Herschelii	Herschel's Telescope.
Triangulum	Triangle.
Triangulum Minus	Lesser Triangle.
Ursa Major	Great Bear.
Ursa Minor	Little Bear.
Vulpecula	Fox.

SOUTHERN CONSTELLATIONS.

Name.	Translation.
Antlia Pneumatica	Air-pump.
Apparatus Sculptoris	Sculptor's Workshop.
Apus	Bird of Paradise.
Ara	Altar.
Argo Navis	Ship Argo.
Avis Solitarius	Owl.
Canis Major	Great Dog.
Canis Minor	Little Dog.
Cela Sculptoria	Graver's Tools.
Centaurus	Centaur.
Cetus	Whale.
Chameleon	Chameleon.
Circinus	Compasses.
Columba	Dove.
Corona Australis	Southern Crown.
Corvus	Crow.
Crater	Cup.
Crux	Cross.
Dorado	Sword-fish.
Equuleus Pictorius	Painter's Easel.
Eridanus	River Po.
Felis	Cat.
Fornax Chemica	Chemical Furnace.
Globus Ætthereus	Balloon.
Grus	Crane.
Horologium	Clock.
Hydra	Water-serpent.
Hydrus	Water-snake.
Indus	Indian.
Lepus	Hare.
Lupus	Wolf.
Machina Electrica	Electrical Machine.
Microscopium	Microscope.
Monoceros	Unicorn.
Mons Mensæ	Table Mountain.
Musca Australis	Southern Fly.
Norma	Rule and Square.
Octans	Octant.
Officina Typographia	Printing Press.
Orion	Orion.
Pavo	Peacock.
Phœnix	Phœnix.
Pisces Australis	Southern Fish.
Pisces Volans	Flying Fish.
Psalterium Georgianum	George's Harp.
Pyxis Nautica	Mariner's Compass.
Reticulus	Net.
Rober Caroli	Charles's Oak.
Sceptrum Brandenburgium	Sceptre of Brandenburg.
Sextans	Sextant.
Solarium	Sun-dial.
Telescopium	Telescope.
Triangulum Australis.	Southern Triangle.
Toucana	American Goose.

"Make friendship with the stars."—MRS. SIGOURNEY.

Q. How are the heavens DIVIDED?

A. They are divided into *groups* or *divisions.*

Q. What are these groups or divisions CALLED?

A. They are called *constellations.*

Q. WHY are the heavens DIVIDED into groups or constellations?

A. Because it would be impossible to designate each star by a *particular name;* therefore it became necessary to separate them into *groups* or *divisions*, which are called constellations.

Q. How are these constellations MARKED upon maps or globes?

A. They are made in the form of *men*, *monsters*, *birds*, *fishes*, *&c.*

Q. WHY were they thus figured?

A. Because the ancients observed certain collections or groups of stars rose or set at certain seasons, for which they always had a symbolical representation of some animal, bird, &c. They also placed their gods among the stars.

Q. Were the stars grouped into constellations by the ANCIENTS?

A. Yes; we read of the ancients being acquainted with Orion, the Pleiades, and the Great Bear, from the most remote antiquity.

Q. Into how MANY constellations did the ancients divide the heavens?

A. Into *forty-eight;* but the moderns have added fifty-eight to that number, making in all one hundred and six.

Q. How were the forty-eight constellations of the ancients DIVIDED?

A. They were divided into *twelve* zodiacal constellations, *twenty-one* of the northern, and *fifteen* of the southern hemisphere.

SECTION I.

Zodiacal Constellations.

Q. Have the names of the zodiacal constellations been CHANGED, or ADDITIONS been made to them?

A. No; they are the *same*, and retain the *same names* as those mentioned by Hipparchus two thousand years ago. (*See Note* 55.)

Q. Are the stars belonging to each constellation designated by PARTICULAR NAMES?

A. Some of the *principal* stars have particular names assigned to them, as Regulus, Arcturus, Capella, &c.; but besides these they have *another designation.*

Q. What other DESIGNATION have they?

A. They are designated by the letters of the *Greek alphabet.* Regulus is also known as α (Alpha) Leonis; Alshain as β (Beta) Aquilæ; and Errai as γ (Gamma) Cephei.

But if there are more stars in any constellation than there are letters of the Greek alphabet, the Roman alphabet is then used, and after that the numbers 1, 2, 3, &c. The first letter of the Greek alphabet usually denotes the brightest star in the constellation; β, (Beta,) the second; γ, (Gamma,) the third, in brilliancy; and so on.

It is not generally known that Sir William Herschel was so well acquainted with the stars, that he could unhesitatingly call every one, down to the sixth magnitude, by its name and letter.

Q. How are the constellations DIVIDED?

A. Into the *zodiacal* constellations, and those of the *northern* and *southern hemisphere.*

Q. What are the ZODIACAL constellations?

A. Those constellations which lie in that *zone* called the *zodiac.*

Q. What is the ZODIAC?

A. A belt or *zone*, extending round the Earth, *sixteen degrees* in width, through the middle of which runs the *ecliptic.*

Q. What are the NAMES of the zodiacal constellations?

A. Their names and their signs are as follows:

♈ Aries, *the Ram.*	♎ Libra, *the Balance.*
♉ Taurus, *the Bull.*	♏ Scorpio, *the Scorpion.*
♊ Gemini, *the Twins.*	♐ Sagittarius, *the Archer.*
♋ Cancer, *the Crab.*	♑ Capricornus, *the Goat.*
♌ Leo, *the Lion.*	♒ Aquarius, *the Water-bearer.*
♍ Virgo, *the Virgin.*	♓ Pisces, *the Fishes.*

ARIES.

Q. Where may the constellation ARIES be found upon a globe or map?

A. Aries, formerly the first constellation of the zodiac, now the *first sign* and second constellation, was situated at the vernal equinox; but owing to precession, that constellation is now removed 30° westward.

As the sidereal year is twenty minutes twenty seconds longer than the tropical year, the equinoctial points have a retrograde motion, called the precession of the equinoxes. About 2000 years ago the equinoctial points were fixed in the constellations Aries and Libra; but the precession equals about 50″ annually, so that now the equinoctial points are 30°, or a whole sign, westward of the places first assigned to them; consequently the sign ♈ (Aries) is now in Pisces, and ♉ (Taurus) in Aries, &c. At this time the constellation Pisces occupies the same place on the zodiac which Aries did 2000 years ago.

Q. How is the constellation Aries KNOWN in the heavens?

A. It is known by *two bright stars*, about 4° apart, which are on the meridian at midnight on the 25th of October.

The brighter of the two stars is called Arietis, or α Arietis; the second, which lies a little to the south-west of Arietis, is called β Arietis, or Sheratan. These two stars are in the head of Aries

TAURUS.

Q. How can TAURUS be distinguished?

A. About the *beginning* of *March* the constellation Taurus may be seen in the *evening* to the east of Arietis, which is then far in the western horizon.

Q. What are the PRINCIPAL STARS in Taurus?

A. The principal stars are two groups, the *Pleiades* and the *Hyades*, and the bright star *Aldebaran.*

Fig. 126.

CONSTELLATION TAURUS.

Q In what DIRECTION are the Pleiades from α Arietis?

A. Almost due *east* from *α* Arietis; and in about an hour and a half after Arietis has *culminated*, the Pleiades will be on the *meridian.*

Q. By what other NAME are the Pleiades known?

A. They are known by the name of the *Seven Stars.*

Q. Where are the HYADES?

A. The Hyades are a group of stars, the brightest of which is about 10° degrees south-east of Alcyone, the brightest star of the Pleiades.

Q. How can ALDEBARAN be found?

A. Aldebaran, known also by the name of *α* Tauri, is the brightest star in the constellation Taurus, and is also reckoned as a star of the first magnitude or brilliancy. It may be found very readily, as it *forms the letter* V *with two bright stars* in the Hyades.

Aldebaran is known as the "Bull's Eye."

Q. What OTHER bright stars are there in Taurus?

A. One in the north horn called *β* or *El Nath*, and one in the *point* of the *southern horn*, about 10° to the south-east of *β*. These two stars form the base of a triangle, of which Aldebaran is the apex.

GEMINI.

Q. What is the NEXT sign in order from Taurus?

A. Gemini.

Q. How is Gemini DESIGNATED on the globes and maps?

A. By the figures of *two children* sitting with their feet resting on the Milky Way.

Gemini is the third sign, but the fourth constellation in the zodiac.

Q. What are the PRINCIPAL stars in the constellation Gemini?

A. The principal stars are *Castor* and *Pollux.*

Q. How can Castor be FOUND in the heavens?

A. It is nearly 30° *east* from *El Nath,* in the end of the Bull's northern horn. Castor is in the *head* of one of the twins.

Q. Is there any thing REMARKABLE about the star Castor?

A. Yes; Castor, when viewed through the telescope, is a *double star;* the smaller one revolves round the larger in about *two hundred and fifty years.*

Q. To what CLASS of stars does Castor belong?

A. To the *second* class; that is, it is a star of the *second magnitude.*

Q. Where is the star Pollux SITUATED?

A. It is about $4\frac{1}{2}°$ *south-east of Castor*, and a line drawn from the Pleiades through El Nath and extended, will touch it.

Q. Is there any thing REMARKABLE about Pollux?

A. It is *quadruple* when seen through the telescope; that is, it is composed of four stars.

Q. By what NAMES do astronomers denote these two stars, Castor and Pollux?

A. Castor is called α (Alpha) *Geminorum*, and Pollux β (Beta) *Geminorum.*

The Twins are also known by the names of Castor and Pollux.

Fig. 127.

Q. What OTHER STARS are there in the constellation Gemini?

A. There is one called *Wasat*, or δ (Delta) Geminorum, which is situated on the ecliptic about 8° south-west of Pollux. There is also a line of three conspicuous stars nearly parallel with Castor and Pollux, and about 20° south-west of them, which designate the feet of the Twins.

Q. Are there any REMARKABLE telescopic objects in this constellation?

A. There is a very singular *double nebula* situated a little south of the bright star Castor, which is partly surrounded by rings, with a bright star in the centre, of which *fig.* 127 is a representation.

Fig. 128.

Q. What OTHER singular telescopic object is there in the constellation Gemini?

A. About 2° south-east of Wasat is a *nebulous star*, which is represented in *fig.* 128, as seen through Lord Rosse's telescope.

CANCER.

Q. What is the FOURTH sign of the zodiac?

A. *Cancer* is the fourth sign, and *fifth* constellation, of the zodiac.

Q. What REMARKABLE object is to be found in the constellation Cancer?

A. A *nebulous group* of minute stars visible to the naked eye, called *Prœsepe*, or the Beehive. It is situated about 15° south-east of Pollux.

Q. What OTHER remarkable star is there in Cancer?

A. Extend a line from Castor through Pollux, and it will reach a star called Tegmine, or ξ (Zeta) Cancri. The telescope shows it to consist of three stars, two of which are close together, and perform a revolution, one round the other, in about *sixty years;* while the third one makes a grand revolution in about *five* or *six hundred years.*

Q. What are the most CONSPICUOUS stars in Cancer?

A. There are no very bright stars in this constellation; the most conspicuous are α (Alpha) and β (Beta) in the southern claw, *Asellus Borealis*, north of Prœsepe, and *Asellus Australis* on the ecliptic, about 3° to the south-east of Prœsepe.

LEO.

Q. What is the FIFTH SIGN of the zodiac?

A. *Leo* is the fifth *sign*, and *sixth* constellation.

Q. What is the PRINCIPAL star in this constellation?

A. Regulus, or α Leonis, a star of the first magnitude, situated about half a degree north of the ecliptic; it is also called the *Lion's Heart.*

Regulus culminates—that is, comes to the meridian—about 8 o'clock in the evening on the 20th of April.

Fig. 129.

Q. Which is the NEXT most brilliant star in this constellation?

A. It is called β or Denebola, a star of the second magnitude, in the Lion's tail, and about 25° east of Regulus.

Q. What FIGURE is usually drawn on the Lion, in maps and globes?

A. The figure of a *sickle.*

Q. What STARS form the sickle?

A. Those stars marked α, (Alpha,) which is Regulus, η, (Eta,) γ, (Gamma,) ξ, (Zeta,) and ϵ, (Epsilon.) *Regulus* is at the *end* of the handle of the

sickle, and the other *five* stars form the blade.

Q. For what is this portion of the constellation REMARKABLE?

A. The November meteors always appear to *radiate* from a *point* in the *bend* of the *sickle*, near the star γ, (Gamma.)

Q. Is the star γ (Gamma) Leonis a REMARKABLE one?

A. It is. When viewed through the telescope it is a *splendid double star*, and moves in an orbit with a period of about a *thousand years.*

Q. Does the telescope reveal any NEBULA in Leo?

A. Yes. In the lower jaw of Leo there is a beautiful *spiral nebula*, which is rendered very distinct by Lord Rosse's large telescope.

Fig. 129 is a correct representation of this singular nebula, which probably consists of many millions of stars.

Q. Is there any OTHER conspicuous object in this constellation?

A. Yes; on the *hind leg of Leo* there is a very singular nebula, having something of a *spiral* form in its *centre.* (See *Fig.* 130.

Fig. 130.

VIRGO.

Q. What is the SIXTH sign of the zodiac?

A. *Virgo* is the *sixth sign*, and *seventh constellation*, of the zodiac.

Q. Has this constellation any CONSPICUOUS star?

A. It has; *Spica*, a star of the first magnitude, is represented in the Virgin's hand.

Q. What is the POSITION of Spica on the globe or map?

A. It lies about 2° south of the ecliptic, and about 20° *east* of the *autumnal equinox.*

Q. What bright star is that in the Virgin's NORTHERN ARM?

A. It is called *Vindemiatrix.* It is a star of the third magnitude, and comes to the meridian about three hours after Regulus, being situated almost due east from the last-named star.

Q. What is the MAGNITUDE of the star in the SOUTHERN shoulder?

A. It is a star of the *third* magnitude, marked β, (Beta,) about 27° south-east from Regulus, both of which lie near the ecliptic.

Q. Is there any REMARKABLE star in this constellation?

A. Yes; a line drawn parallel to the ecliptic from β, (Beta,)

called also *Zavijava*, and extended 14°, would reach the star in the *Virgin's side*, called γ (Gamma) *Virginis*.

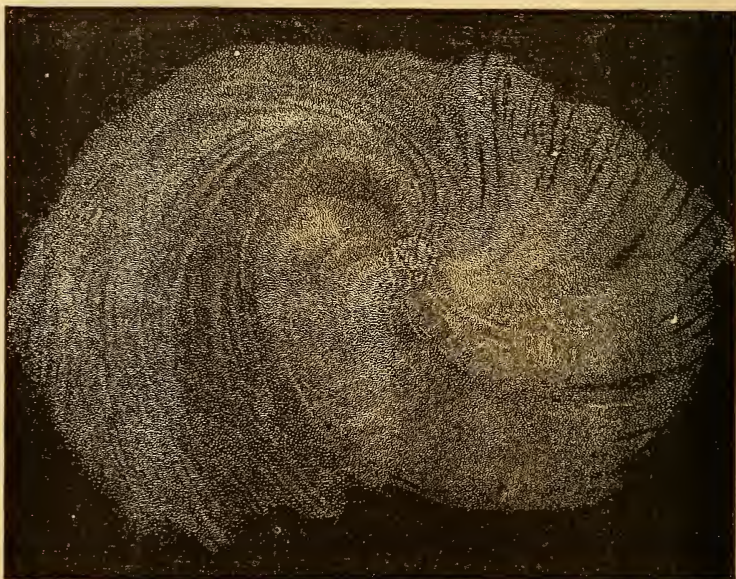
Q. For what is this star NOTED?

A. It is a binary star,—one revolving round the other in a *highly elliptical orbit* in the period of about *one hundred and eighty years.*

Q. Mention the other prominent stars in this constellation.

A. About half-way between *Vindemiatrix* and γ (*Gamma*) is the star δ, (*Delta;*) between β (*Beta*) and δ (*Delta*) is a rich cluster of *nebulæ*. About 10° south-east from δ is ξ, (*Zeta,*) on the knee; and about 12° east of Spica are two stars, 3° apart, which designate the Virgin's foot.

Fig. 131.



The above figure represents a spiral nebula in the northern wing of Virgo, as it appears through Lord Rosse's great telescope.

LIBRA.

Q. What is the SEVENTH SIGN of the zodiac?

A. Libra is the *seventh sign*, and *eighth* constellation.

Q. When does the Sun ENTER this sign?

A. About the *twenty-third of September;* but he does not enter the *constellation* till about the *twenty-fifth of October.*

Q. How may Libra be DISTINGUISHED?

A. It lies *east* of Virgo, and contains four stars—one of the third,

and three of the fourth, magnitude. These four stars form a trapezium.

Q. How are the TWO divisions of the Scales distinguished?

A. The brightest star of the four, called Zubeneschamali, or α Libra, and the star south-east of it, forming the southern boundary of the square, are in the southern scale; and the star marked β, (Beta,) or Zuben-el-Gamabi, and the star marked γ, (Gamma,) designate the northern scale.

Q. Is there any REMARKABLE OBJECT in this constellation?

A. About 7° south-east of Zubeneschamali is a nebulous cluster of minute stars, which Sir William Herschel pronounced to be a "*nebulosity not of a starry nature.*" This wonderful object is 12° due south of β (Beta) Libra.

Q. Is there any OTHER object worthy of note in this constellation?

A. About 12° due north of Zuben-el-Gamabi is a close cluster of stars, in which Sir William Herschel, with his large telescope, counted more than two hundred stars.

Fig. 132.

This splendid cluster, of which *fig.* 132 is a representation, was so closely compressed in the centre that the individual stars could not be counted by Sir Wm. Herschel.

SCORPIO.

Q. What is the NEXT sign in order from Libra?

A. *Scorpio*, the *eighth sign*, and *ninth constellation.*

Q. In what MONTH does the Sun enter this sign?

A. About the *twenty-third of October;* but he does not enter the constellation until about the *twentieth* of November.

Q. What is the PRINCIPAL STAR in this constellation?

A. The brilliant red star of the first magnitude called *Antares;* also called α Scorpii or *Cor Scorpii.*

Q. When can this beautiful star be seen on the MERIDIAN?

A. About 8 o'clock in the evening on the *twenty-sixth of July.*

Q. Where is the NEXT most conspicuous star in this constellation?

A. In the Scorpion's head, about 8° north-west of Antares. This star is called β (Beta) or *Graffias.*

Q. How can the SITUATION of Graffias be determined?

A. It is near the *centre of an arc* formed of several stars, which, together with Antares, resemble the body of a *paper kite.*

Fig. 133.

Fig. 133 represents the principal stars in the constellation Scorpio. The *right* hand, it will be remembered, is *west,* and the *left* hand, *east,* or contrary to terrestrial maps.

Q. How are the OTHER STARS in this constellation designated?

A. South of Antares, stretching off to the south-east, there is a line of stars which form a curve resembling the *tail* of the kite.

These stars form the tail of Scorpio.

Q. Is there any REMARKABLE OBJECT in this constellation?

A. About 4° north-west of Antares there is a *globular cluster* of stars in an apparent blank space in the heavens. The centre is one blaze of light, while the edges shade off into nebulosity.

Fig. 134.

Whenever Sir William Herschel found a blank space in the heavens, he was accustomed to say to his assistant in his observatory—"Make ready to write, nebulæ are just approaching." And such he always found to be the case.

Q. What DESCRIPTION of nebula may be found in Scorpio?

A. There is a cometary nebula in the tail of Scorpio, which is represented in *fig.* 134.

SAGITTARIUS.

Q. Which is the NINTH sign of the zodiac?

A. Sagittarius is the *ninth* sign, and *tenth* constellation, of the zodiac.

Q. When is the SUN in this sign?

A. In *November*, and enters the *constellation* in *December*.

Q. Are there any stars of the FIRST magnitude in this constellation?

A. No; there are no stars of the *first* or *second* magnitude in Sagittarius.

Q. How may this constellation be FOUND in the heavens?

A. It lies *east of Scorpio*, and can be distinguished by *five* stars, four of which form a quadrilateral figure; the whole is called the *Milk-dipper*, as it lies partly in the Milky Way.

Q. Describe the OTHER PARTS of this constellation.

A. Five small stars directly north of the Milk-dipper form the *head* of the Archer, and three others on the back of the animal form a *small triangle.*

Q. Are there any CONSPICUOUS objects in this constellation?

A. Not far from the point of the winter solstice is a fine globular cluster of stars, which the telescope reveals as a rich group, with five minute stars near it.

This cluster was for a time considered as a nebula, until Sir William Herschel first resolved it into stars by means of his great telescope.

Fig. 135.

Near this cluster is a beautiful nebula, having three lobes, forming together a circular nebula with a dark space in the centre, in which may be seen three small bright stars by reference to the above figure.

CAPRICORNUS.

Q. What is the next constellation EAST of Sagittarius?

A. *Capricornus.*

Q. What SIGN and CONSTELLATION is Capricornus in the order of the zodiac?

A. It is the *tenth sign*, and *eleventh constellation.*

Q. When does the Sun enter the SIGN Capricornus?

A. On the 21*st of December* the Sun enters the sign, but does not reach the constellation till the 20*th of January.*

Q. What is that PERIOD designated by the entrance of the Sun into the sign Capricornus called?

A. It is called the *winter solstice.*

Q. Where is the Sun VERTICAL at the time of the winter solstice?

A. He is vertical to all places on the Earth situated under the *tropic of Capricorn.*

At this period the inhabitants of the northern hemisphere have their shortest days, and the north pole is in darkness. The inhabitants of the southern hemisphere enjoy summer, and the southern pole is illuminated.

Q. Are there any BRILLIANT stars in this constellation?

A. No; *none* of the stars in this constellation are *above* the *third magnitude.*

Q. Are there any remarkable telescopic objects in Capricornus?

A. There are some clusters, one of which, only the thirtieth part of a degree in diameter, contains *hundreds* of stars.

Fig. 136.

Fig. 136 represents a cluster situated about twenty degrees north-west of the bright star Fomalhaut. This cluster is very brilliant, and is supposed to be at a vast distance from our system.

AQUARIUS.

Q. What is the ELEVENTH sign of the zodiac?

A. Aquarius is the *eleventh sign*, and *twelfth constellation.*

Q. Where is this constellation SITUATED?

A. To the *east* of Capricorn.

Q. How is it REPRESENTED on maps and globes?

A. By the figure of a *man* with an *urn* in his hand, from which runs a *stream of water.*

Q. Are there any CONSPICUOUS stars in this constellation?

A. There are *no stars* of the first magnitude in the constellation Aquarius.

Q. Mention the PRINCIPAL stars in Aquarius.

A. The star α, (Alpha,) in the *eastern shoulder*, and β, (Beta,) in the *western*, are of the third magnitude. *Ancha*, a star of the third magnitude, is in the waist of Aquarius. In the urn are five stars forming a Y, with the top of the letter pointing south-east. *Scheat*, a star of the third magnitude, is in the calf of the right leg.

Q. Are there any REMARKABLE OBJECTS in this constellation?

A. There is a *planetary nebula* in the constellation Aquarius, situated about eight degrees south-west of β, (Beta,) in the shoulder.

Q. What is this nebula REMARKABLE for?

A. It is said to resemble the planet *Venus*, is very bright, and has a pale blue tint. Its disc is somewhat *elliptical.*

Q. Has this object ever been MEASURED?

A. It has. Sir John Herschel values its apparent diameter at $20''$ angular measurement, which is the one hundred and eightieth part of a degree.

Q. Has its MAGNITUDE ever been estimated?

A. It is supposed, if this object be only as distant from us as the stars, its real dimensions must be such as would fill the whole orbit of Uranus.

Q. What would be the SOLID CONTENTS of a body large enough to fill the orbit of Uranus? that is, a body whose diameter is three thousand six hundred millions of miles?

A. Such a body would contain within its periphery more than *sixty-eight thousand millions* of globes as large as our Sun!

Fig. 137.

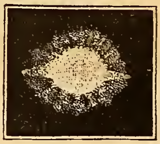


Fig. 137 is a representation of this nebula as it appears in a large telescope.

Q. Is there any OTHER telescopic object of interest in this constellation?

A. About 10° north of the last-mentioned nebula is a *fine globular cluster*, which the telescope shows to be composed of *tens of thousands of stars.*

Q. Is this object visible by the NAKED EYE?

A. No; it requires the best telescopes to resolve it into stars, which are crowded together, as Sir John Herschel says, "like a heap of fine sand."

Fig. 138.

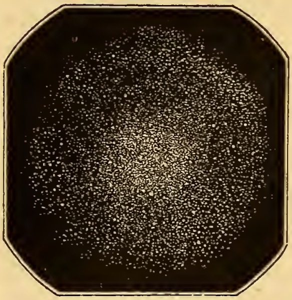


Fig. 138 is a representation of the above-named cluster.

PISCES.

Q. What is the TWELFTH sign of the zodiac?

A. *Pisces* is the twelfth sign, and *first* in order.

Q. How is this constellation REPRESENTED on the globes and maps?

A. It is represented by *two fishes* some distance apart, united by a long ribbon, each end of which is tied round the tail of one of the fishes.

Q. What GREAT CIRCLE passes through this constellation?

A. The *equinoctial colure.*

Q. When the sun is in Pisces, what SEASON is it?

A. The Sun enters the *constellation* Pisces and the *sign* Aries on the 20*th of March*, at the time of the vernal equinox.

Q. Are there any BRIGHT stars in the constellation Pisces?

A. No; all the stars in this constellation are *small*, lying between Aries on the east and Aquarius on the west. West and north-west of Arietis are eight or ten small stars, which form the Northern Fish; the ribbon which attaches the fishes may be identified by means of three or four small stars leading south-east as far as within a degree of the equinoctial, where we find the star El-Rischa, of the third magnitude, in the loop of the ribbon, which now takes a westerly course as far as the equinoctial colure, and is there united to the tail of the other fish. β (Beta) and γ, (Gamma,) in the head, are the principal stars in the western fish.

SECTION II.

Northern Constellations.

Q. What is understood by the RISING and SETTING of the stars?

A. Their *appearance above* and *disappearance beneath* the horizon.

Q. Do all the stars sink below the horizon of all the places on the Earth?

A. No; some stars *never rise or set*, but are always above the horizon, to the inhabitants north or south of the equator.

Q. How do those stars which never rise or set APPEAR TO MOVE ?

A. They appear to *revolve round the pole* of the heavens.

Q. What are those stars CALLED which never rise or set, but appear to move round the pole of the heavens?

A. They are called *circumpolar* stars.

Q. What are the NORTHERN constellations?

A. Those constellations lying *north* of the *zodiac.*

URSA MAJOR.

Q. What is the MOST CONSPICUOUS of the northern constellations?

A. The constellation *Ursa Major*, or the Great Bear.

Q. How can the constellation Ursa Major be IDENTIFIED ?

A. By *seven bright stars*, which are on the meridian in the evening about the 5th of May; and to all places between 50° and 60° of north latitude they will be overhead.

Fig. 139.

"He who would scan the starry skies,
Its brightest gems to tell,
Must first direct his mind's eye north,
And learn the Bear's stars WELL."

These seven stars are sometimes called the "*Wagon*," and by some the "*Dipper*;" four of the stars serve to form the bowl, and the other three the handle of the Dipper.

Q. What are the NAMES of the stars in the handle of the Dipper?

A. *Benetnasch* or η (Eta) is in the end of the handle, or tail of the Bear, *Mizar* or ζ (Zeta) in the middle, and *Alioth* or ε (Epsilon) next the bowl of the Dipper.

Q. What PART of the CONSTELLATION do these stars occupy?

A. They form the *tail* of the Great Bear.

When the constellation is on the meridian, between the zenith and the pole, these three stars in the tail point towards the east, or the left hand of the picture. The Arabians believed these seven stars to resemble a bier and mourners, hence the star in the end of the tail is called *Benetnasch,* which means in Arabic the *chief,* as it represented the chief of the mourners.

Q. Is there any thing REMARKABLE in either of the THREE STARS in the tail of Ursa Major?

A. The *middle* star of the three, called Mizar, is *double* when seen through the telescope.

By the naked eye a small star may be detected near Mizar, which, however, is more than 700″ distant from it. This small star is called Alcor, and by some is thought to be the attendant of Mizar; but this mistake is rectified as soon as the telescope is applied, which shows Mizar double, and Alcor at some distance from it.

Q. What is the ANGULAR DISTANCE between Benetnasch and Mizar?

A. Nearly *seven degrees.*

Q. What is the ANGULAR DISTANCE between Mizar and Alioth, the third star in the tail?

A. About *four degrees.*

Q. There are two stars in this constellation so situated that a line drawn through them and extended will pass through the north pole: what STARS ARE they?

A. When the Dipper is on the meridian, they are the two most *westerly* stars of the Dipper; the name of the northern one is α, (Alpha,) or *Dubhe;* that of the southern is β, (Beta,) or *Merak.* They are also called the *Pointers,* because they point to the pole.

These seven stars constitute only a *part* of the constellation Ursa Major.

"With what a stately and majestic step
That glorious constellation of the north
Treads its eternal circle!"

Q. What are the NAMES of the two other stars which, together with the Pointers, form the Dipper?

A. They are called δ, (Delta,) or *Megrez;* and γ, (Gamma,) or *Phad.*

Q. What is there remarkable in the SITUATION of Megrez?

A. It is situated within seven and a half minutes of the *equinoctial colure.*

Formerly the Grecians guided their ships at night by means of the constellation Ursa Major; and Manilius, a poet who flourished in the first century before Christ, says—

"Seven equal stars adorn the Greater Bear,
And teach the Grecian sailors how to steer."

Q. To what PLACES of the Earth are the seven stars of the Great Bear always above the horizon?

A. To all places *north* of *forty-one* degrees north latitude.

Although the seven stars never set at all places at, and north of, 41° north latitude, yet the *constellation* is not wholly above the horizon at those places, for, by reference to the globe or map, it will be seen that the *whole* of the constellation is always above the horizon at all places north of 58° north latitude.

Q. How may the OTHER PARTS of this constellation be known?

A. About *fifteen degrees* east of the Pointers is a collection of

stars which form the face; and when the constellation is on the meridian, a line drawn through the Pointers and extended about twenty degrees farther south, will reach two stars on the eastern hind foot; about fifteen degrees west of these are two other stars, which form the other hind foot; and about ten degrees farther west are two more stars similarly situated, which form one of the fore feet.

Q. Are there any remarkable TELESCOPIC OBJECTS in the constellation Ursa Major?

A. About *twelve degrees* south of β, (Beta,) one of the Pointers of the Great Bear, is a very *singular nebula*, with two bright spots in the centre.

Fig. 140.

Fig. 140 is a correct copy of the nebula, as it appeared in the great telescope of Lord Rosse.

Fig. 141.

There is also a beautiful oval nebula about ten degrees south of Megrez, with a white nucleus, as will be seen by reference to *fig.* 141.

URSA MINOR.

Q. In what CONSTELLATION is the Pole Star?

A. In the constellation *Ursa Minor.*

Q. How can it be DESIGNATED?

A. A line drawn through the two Pointers, α (Alpha) and β, (Beta,) of Ursa Major, and extended nearly *thirty degrees* to the north, will designate the Polar Star.

Q. How MANY CONSPICUOUS stars are there in this constellation?

A. There are *seven* brighter than the rest, one of which is of the second magnitude, two of the third, and four of the fourth magnitude.

Q. What FORM has this collection of stars?

A. It is in the form of a *dipper*, and bears a strong resemblance to the seven stars in the Great Bear.

Q. In what PART of the constellation is the Polar Star?

A. In the extremity of the handle of the Dipper; it is represented in the end of the tail of the Lesser Bear.

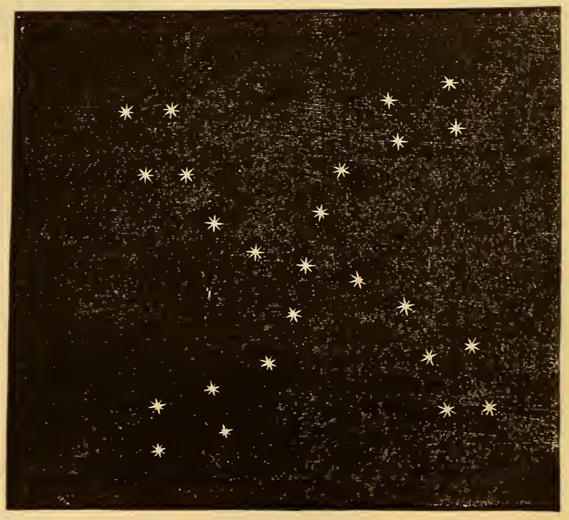
Q. Does the Polar Star appear to MOVE?

A. No; unless viewed with a good instrument, it does not seem to partake of the apparent diurnal motion of the other heavenly bodies, but appears perfectly *stationary*.

Q. What EFFECT is produced in the appearance of the constellation Ursa Minor by the diurnal rotation of the Earth?

A. It appears as if swung round by the tail, the extremity of that appendage being at rest.

Fig. 142.



In the above figure the constellation Ursa Minor is represented in four different positions, as it appears to revolve round the pole. After every interval of six hours its situation changes from one position to the next, till the revolution is completed, the star in the tail, which represents the Polar Star, being apparently at rest.

Q. Does the Pole Star OCCUPY EXACTLY the pole of the heavens?

A. No; it is *one degree and a half* from the pole of the heavens. It will gradually approach to within half a degree

from the pole, and in about 13,000 years hence it will be nearly 49° from the celestial pole. (*See Note* 54.)

In the infancy of navigation, before the compass was known, mariners were guided solely by the North Star, which Dryden thus describes:

"Rude as their ships were navigated then,
No useful compass, or meridian known,
Coasting, they kept the land within their ken,
And knew no north, but when the Pole Star shone.'

The Pole Star is also known by the names of *Cynosura* or *Alrucaba,* which last name is derived from the Arabic.

Q. How does the POLE STAR APPEAR through a powerful telescope?

A. It appears *double.*

Q. How may the OTHER STARS of the Little Dipper in Ursa Minor be found?

A. By extending a line through Megrez and Phad of the Great Dipper in Ursa Major, it will strike one of the four stars in the Little Dipper, called Kochab. The other three stars, together with Kochab, form the Little Dipper, of which the Polar Star occupies the end of the handle.

About three and half degrees south-west of Kochab, when the latter is on the meridian above the pole, is a star marked γ (Gamma) on the maps. This star and Kochab are called the *Guards.*

Kochab is so called from an Arabic word which signifies the North Star, because in the time of Ptolemy that star was nearer to the pole than the present Polar Star.

LEO MINOR.

Q. When Ursa Major is on the meridian, what OTHER CONSTELLATION is on the meridian SOUTH of it?

A. *Leo Minor.*

Q. Where is Leo Minor SITUATED?

A. It is situated directly *between Ursa Major* on the north, and *Leo Major*, one of the zodiacal constellations, on the south.

Q. Does Leo Minor contain any FIRST-CLASS stars?

A. No; Leo Minor contains *no stars* of the *first* or *second* magnitude, and but *one* of the *third*, the others being still less brilliant.

Q. How may the principal star in Leo Minor be DESIGNATED?

A. It forms nearly an equilateral triangle with Denebola and Regulus; the former is in the tail, the latter in the heart, of Leo Major.

Q. How may the OTHER STARS of this constellation be found?

A. They consist of a collection of small stars which lie chiefly to the north of the head of Leo Major.

This constellation is on the meridian at the same time as Regulus.

Q. Are there any remarkable TELESCOPIC OBJECTS in Leo Minor?

A. There is a *bright nebula* four degrees from ξ (Xi) Ursa Major, on a line between that star and Regulus.

Q. What APPEARANCE has this object when seen through the telescope?

A. It is a *bright globular nebula*, which more powerful instruments than those now in use may resolve into stars, showing it to be a grand globular cluster.

"In other words, not only suns beyond suns, but glorious systems of suns arranged in harmonious order." Our solar system, although it is *five thousand seven hundred millions of miles in diameter*, is a mere *point* in the universe. Smyth says—"Should it (our system) be taken for an average among the millions of suns around, what imagination can grasp the immensity of creation! Indeed, where system thus stretches beyond system, the space must be infinite; and in such contemplation we become conscious of our own littleness. No subject whatever, except revelation, can give a more exalted conception of the Eternal Fountain of all intelligence."

CANES VENATICI.

Q. Where is Canes Venatici SITUATED?

A. A little to the *south-east* of the Great Bear.

Fig. 143.

Q. How is this constellation REPRESENTED on globes and maps?

A. By *two greyhounds* tied together by a ribbon around their necks.

Q. What are the NAMES of these greyhounds?

A. The northern is called *Asterion*, and the southern one, *Chara*.

Q. Is there any remarkable TELESCOPIC OBJECT in this constellation?

A. Yes; a *wonderful nebula* exists near the ear of Asterion, the northern Hound, and not far from Benetnasch, in the tail of Ursa Major.

Fig. 143, on the opposite page, represents this nebula as seen through Lord Rosse's telescope. (*See Note* 55.)

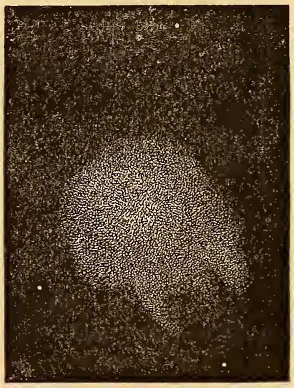
Q. What OTHER remarkable telescopic object is there in Canes Venatici?

A. There is a great globular cluster just *east* of the *southern Hound.*

Q. Does this cluster consist of MANY stars?

A. It consists of not less than *one thousand* small stars, having a blaze of light in the centre, and a sort of fringe of stars round one side.

Fig. 144.



The cluster represented in *fig.* 144 is one of those closely-compacted combinations of stars which indicate some general bond of union or attraction between their constituents.

COR CAROLI.

Q. Are there any stars of the FIRST magnitude in the constellation Cor Caroli?

A. No; the brightest star called Cor Caroli, or 12 Canum Venaticorum,* situated in the new constellation Cor Caroli, is of the third magnitude.

The constellation Cor Caroli is situated between the Greyhounds Asterion and Chara. This constellation was formed by Halley, and called Cor Caroli, or Charles's Heart, at the suggestion of Sir Charles Scarborough, who was a great mathematician, and also physician to King Charles.

Q. How can Cor Caroli be DETECTED on the map or in the heavens?

A. Its place may be found by drawing an imaginary line from

* *Canum Venaticorum* is the genitive of *Canes Venatici*.

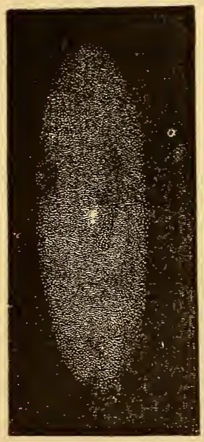
the *Pole Star* through *Alioth*, in the tail of the Great Bear, when that constellation is on the meridian, and extended *seventeen degrees* farther south.

Cor Caroli appears a double star when viewed through a good telescope.

Q. Are there any REMARKABLE objects in this constellation?

A. Except Cor Caroli, this constellation offers nothing remarkable to the unassisted eye.

Fig. 145.



COMA BERENICES.

Q. How may the constellation Coma Berenices be DISTINGUISHED?

A. It lies *south* of Canes Venatici, and *north* of the tail of Leo.

Q. Has Coma Berenices any CONSPICUOUS stars?

A. It has *not:* all the stars in this constellation are *below* the *third* magnitude. The principal cluster lies between Cor Caroli and Denebola, in the tail of Leo.

Q. Are there any wonderful TELESCOPIC OBJECTS in this constellation?

A. About twenty degrees west of the bright star Arcturus the telescope reveals the magnificent nebula represented in the annexed figure.

BOÖTES.

Q. How is Boötes REPRESENTED on the globes and maps?

A. He is represented as a *man* with a *club* in one hand; the other is raised in which he holds the *ribbon* which is attached to the hounds Asterion and Chara.

Boötes is called the Bear-driver, and is represented as driving the Great Bear round the north pole.

Q. What is the PRINCIPAL STAR in the constellation Boötes?

A. Arcturus, or α (Alpha) Boötes.

Q. How may Arcturus be FOUND?

A. About the middle of June, at nine o'clock in the evening, it may be seen on the meridian. An imaginary line drawn through the two stars in the end of the tail of Ursa Major, and extended about 30°, will point out Arcturus.

Spica in Virgo, Denebola in the tail of Leo, Cor Caroli, and Arcturus form a quadrilateral figure.

Q. There is a star in each shoulder of Boötes: how can they be FOUND?

A. About *twenty degrees* east of Cor Caroli is γ (Gamma) or Seginus, in his left shoulder, and about *ten* degrees south-east of

Seginus is δ, (Delta,) in the right shoulder. These two stars form, with Arcturus, an isosceles triangle, Arcturus being the apex.

Q. What OTHER STARS are there in this constellation?

A. In the face is β, (Beta,) which forms a triangle with the stars on the shoulders; and a line drawn from δ (Delta) to Arcturus leaves Mirach or ε (Epsilon) on the east.

Q. Is there any thing REMARKABLE about Mirach?

A. It is a double star, one of which revolves about the other in a period of *nine hundred and eighty years.*

MONS MÆNALUS.

Q. By WHOM was the constellation Mons Mænalus formed?

A. By *Hevelius.* It is situated under the feet of Boötes, and contains no conspicuous stars.

QUADRANS MURALIS.

Q. Are there any CONSPICUOUS stars in the constellation Quadrans Muralis?

A. There are *not.*

Q. Where is this constellation SITUATED?

A. Immediately *north* of Boötes.

CORONA BOREALIS.

Q. Where is Corona Borealis, or the Northern Crown, SITUATED?

A. *East* of Boötes.

Q. What is the FORM of this constellation?

A. It is of a *circular* form; *seven stars* serve to make the figure of *part* of a circle.

Q. What is the PRINCIPAL star in this constellation?

A. The *middle* one of the seven: it is called *Alphecca*, or α (Alpha) Coronæ Borealis.

Alphecca comes from the Arabic words *al fekkah,* the dervish's cup or platter, from the incomplete circle formed by these stars.

Q. Is there any TELESCOPIC object of note in Corona Borealis?

A. Yes; about *ten degrees* to the north-east of Alphecca is a binary star, marked ς (Sigma) on the maps. One star of this system performs its revolution around the other in about *five hundred and sixty years.*

HERCULES.

Q. How is the constellation Hercules REPRESENTED on the maps and globes?

A. By a man in a *kneeling* posture, clothed with a *lion's skin*, with a *club* in one hand, and the three-headed dog *Cerberus* in the other.

Q. Where is the principal star of this constellation SITUATED?

A. In the *face* of Hercules.

Q. What is the NAME of this star?

A. It is called α (Alpha) *Herculis*, or more generally *Ras Algethi.*

Ras Algethi is a word derived from the Arabic *rás-al-játhi*, the *kneeler's head*, because it is in the head of Hercules, who is in a kneeling posture.

Q. When may Ras Algethi be seen in the MERIDIAN?

A. About the *thirtieth* of July, at *nine* o'clock in the evening.

Q. What other CONSPICUOUS stars are there in this constellation?

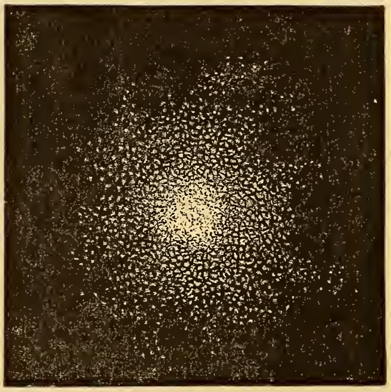
A. One on the western shoulder, called β (Beta) or *Korneforos*, situated about midway between Ras Algethi and Alphecca, in Corona Borealis; about three degrees to the south-west of Korneforos is a star marked γ, (Gamma.)

On the body of Hercules are four stars from five to eight degrees apart, which form a quadrilateral figure.

Q. What remarkable telescopic object is there in the constellation Hercules?

A. Eight degrees north of Alphecca, in Corona Borealis, just under the western heel of Hercules, is a telescopic cluster or *ball* of stars of extraordinary brilliancy.

Fig. 146.



Dr. Nichol says, that "no representation can give a just conception of this magnificent cluster. Perhaps no one ever saw it for the first time through a telescope without uttering a shout of wonder."

Q. What is λ (Lambda) Herculis noted for?

A. This star, λ (Lambda) Herculis, situated in the eastern arm of Hercules, is noted as being the star towards which the whole solar system is slowly journeying.

This theory of the slow motion of the solar system towards λ (Lambda) Herculis was first promulgated by Sir William Herschel; a hypothesis which the researches of M. Argelander serve to strengthen.

OPHIUCHUS.*

Q. How is the constellation Ophiuchus REPRESENTED on the maps and globes?

A. It is represented as a man holding a *serpent* in his hands.

Q. Where is this constellation SITUATED?

A. *South* of *Hercules*, the equator dividing it nearly equally.

Q. What is the PRINCIPAL star in this constellation?

A. *Ras Alhague*, a star of the second magnitude, in the head of Ophiuchus.

The name is derived from the Arabic *rás-al-hawwá*, "the serpent-charmer's head."

Q. How can the PLACE of Ras Alhague be identified?

A. It is situated about *five and a half degrees* south-east of Ras Algethi, the bright star in the constellation Hercules.

Q. Are there any stars in this constellation of the FIRST magnitude?

A. There are *not.* There is a star of the third magnitude on the eastern shoulder, marked β, (Beta,) and one of the fourth magnitude on the western shoulder, marked κ, (Kappa,) which, with Ras Alhague, form a triangle.

Q. How far BELOW the EQUATOR does this constellation extend?

A. It extends about *twenty degrees* below the equator, where there is a star marked ρ, (Rho,) which designates the southern foot.

The other stars belonging to this constellation may be easily learned by reference to the globe or map.

SERPENS.

Q. How is the constellation Serpens DELINEATED?

A. By a *serpent* which Ophiuchus holds in his hands, the head of which is south of Corona Borealis, and between Boötes and Hercules; it is then entwined round the western arm of Ophiuchus, under his western knee, and passes into his eastern hand, makes one loop, and ends in the Milky Way.

Q. Are there any CONSPICUOUS STARS in Serpens?

A. There are *none* of the first magnitude; one of the *second* magnitude is to be found by drawing a line from Alphecca, in Corona Borealis, nearly south twenty degrees.

Q. What is the NAME of that star?

A. It is called α (Alpha) Serpens, or *Unúk-al-Hay*, which means the *serpent's neck.*

Q. How is the head of Serpens DISTINGUISHED?

A. By a cluster of *five* stars south of Corona and west of Hercules.

---

* This constellation is sometimes called *Serpentarius.*

Q. Which are the PRINCIPAL stars in the head?

A. Of the *five* stars of the head, there are *two* of *equal magnitude*, which are about two degrees apart; the most westerly of these two stars is called β, (Beta,) the other, γ, (Gamma,) Serpentis.

DRACO.

Q. Where is DRACO situated?

A. It is represented by a *serpent*, whose head is immediately *north* of the *eastern foot* of Hercules, and after making several loops, its tail passes between Ursa Major and Ursa Minor; thus it is said to *separate* the two Bears.

Q. How can the HEAD of Draco be distinguished

A. About *midway* between the pole star and Ras Alhague is a bright star called β (Beta) Draconis, or *Rastaben;* about four degrees a little to the south-east of Rastaben is a star called γ (Gamma) Draconis, or *Etanin;* north of Etanin is ξ (Xi) Draconis, or *Grumium.* Four degrees north of Rastaben is a small star, which, with Rastaben, Etanin, and Grumium, forms a quadrilateral figure. To the west of this four-sided figure is a small star, (*El Rakis,*) which forms the apex of a triangle, the base being Etanin and Grumium. These five stars form the letter V, and designate the head.

Q. Which of the stars in the head is most NOTED?

A. *Etanin.*

Q. Why is ETANIN a NOTED star?

A. Because, as it passes very near the *zenith* of Greenwich, it was selected as being a suitable star to observe, in order to ascertain the *parallax of the Earth's orbit*, and by that means to obtain some general idea of the distances of the fixed stars.

Q. Was the parallax of Etanin, γ (Gamma) Draconis, DISCOVERED then?

A. No: Dr. Bradley *failed* to discover the *parallax* of the star, although his observations were made with the most rigorous exactness, on a base comprising the diameter of the Earth's orbit, that is, of one hundred and ninety millions of miles; yet this immense distance was not appreciable by *any instruments then in use.*

From these observations, Dr. Bradley estimated the distance of γ (Gamma) Draconis to be at least *four hundred thousand times* more distant than the Sun.

Q. What important DISCOVERY did Bradley make in his endeavors to determine the parallax of Etanin?

A. He discovered the *aberration of light.*

Q. Is there any OTHER noted star in Draco?

A. Yes; there is one which is on the *meridian with Arcturus,*

and is situated between the tail of Ursa Major and the head of Ursa Minor.

Q. What is the NAME of this star?

A. It is called *Thuban*, or *α* (Alpha) Draconis.

Q. For what is Thuban NOTED?

A. About *four thousand six hundred years ago* it was the *pole star*. (*See Note* 54.)

Q. How FAR is it from the pole now?

A. Nearly *twenty-five degrees.*

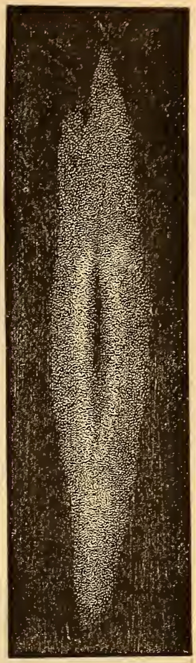
Q. When Thuban was the pole star, how did it appear during a diurnal revolution of the Earth?

A. A diurnal revolution of the Earth causes all the heavenly bodies to appear to revolve; but as Thuban then occupied the place of the pole, it appeared *stationary.*

Q. Is any remarkable NEBULA to be seen, by the aid of a telescope, in the constellation Draco?

A. Under the body of the Dragon is a bright *oval* nebula, very much *elongated*, with a dark line in the centre, as in *fig.* 147.

Fig. 147.



CERBERUS.

Q. Where is Cerberus SITUATED?

A. *East* of Hercules.

Q. How is Cerberus REPRESENTED?

A. As a *three-headed dog*, which Hercules holds in his hand.

Q. Are there any CONSPICUOUS stars in Cerberus?

A. There are *not.*

LYRA.

Q. How is Lyra REPRESENTED on the maps?

A. By a *harp.*

Q. Are there any BRIGHT stars in the constellation Lyra?

A. There is one star of the *first magnitude* in this constellation.

Q. What is the NAME of this star?

A. *Wega*, or *α* (Alpha) Lyræ.

Q. Where is Wega SITUATED?

A. It is the first bright star to the *north-east* of Ras Alhague, and with the Pole Star and Arcturus, it forms a *large triangle.* It also forms a triangle with two small stars about two degrees from it.

Q. Near what POINT in the heavens will Wega be situated at some future time?

A. Wega will be situated within *five degrees of the north pole.*

15

Q. How LONG will it be before Wega will be our pole star?

A. Wega will be our pole star about *ten thousand years* hence.

Q. How FAR is Wega north of the equator?

A. About *thirty-eight and a half degrees.*

Wega passes within a quarter of a degree of the zenith of the Washington Observatory.

Q. Has the distance of Wega from our system been ESTIMATED?

A. Yes; its distance is computed to be more than *one hundred and forty-two billions* of miles from our Sun.

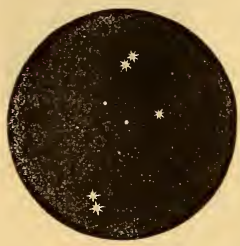
Q. What OTHER STARS are there in Lyra?

A. Five degrees to the south-east of Wega is a star of the *fourth magnitude*, marked δ (Delta) on the maps and globes; about five degrees to the south of δ (Delta) is another star, β, (Beta,) of the *third magnitude;* two degrees to the south-east of β (Beta) is γ, (Gamma,) of the *fourth magnitude.*

Q. Are there any REMARKABLE OBJECTS in the constellation Lyra?

A. *A degree and a half* to the north-east of Wega is the star ε, (Epsilon,) which the telescope shows to be multiple.

Fig. 148.



This star appears double with even a low power; but by applying superior telescopes, each component of the double star is again divided, thus forming two pairs of stars, as will be seen in the figure. Between these pairs will be found three small telescopic stars of the thirteenth magnitude. Of these two systems, the stars composing that on the north (which is at the bottom of the figure) we will call A B, and those on the south, or top of the figure, C D. It is supposed that B will revolve round A in about two thousand years, and C around D in one thousand years, and that the two binary systems will require nearly a million of years to perform their revolution round the central ones. But what is this duration, when compared to that astounding unit of time—the grand revolution of the whole creation!

"To Thee I bend the knee; to Thee my thoughts
Continual climb; who, with a master hand
Hast the great whole into perfection touched."—THOMSON.

Q. What TELESCOPIC OBJECT is that situated between β (Beta) and γ (Gamma) Lyræ?

A. It is an annular nebula or ring.

Sir William Herschel estimated the distance of this nebula from our system to be nine hundred and fifty times that of Sirius—at least *forty-seven thousand billions of miles.*

Q. Is there any other wonderful TELESCOPIC OBJECT in the constellation Lyra?

A. About *five and a half* degrees south-east of β (Beta) is a globular cluster which is estimated at *one thousand three hundred billions* of miles from our system.

Fig. 149.

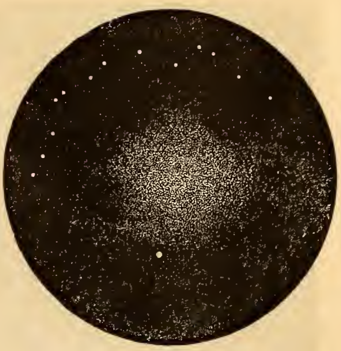


Fig. 149 is a representation of this superb cluster, with a semicircle of small stars near it.

TAURUS PONIATOWSKI.

Q. Where is Taurus Poniatowski situated?

A. The *face* of the animal is near the point where the *solstitial colure* crosses the *equinoctial.*

Q. Are there any REMARKABLE STARS in this constellation?

A. There are *not.* A few small stars form the letter V, which are thought to resemble the Hyades and Aldebaran in the zodiacal constellation Taurus.

SCUTUM SOBIESKI.

Q. How may this constellation be FOUND on the globes and maps?

A. It is represented as a *shield* with a *cross* in its centre, immediately *south* of Taurus Poniatowski.

Q. Are there any BRIGHT STARS in Scutum Sobieski?

A. There are *none.*

Q. Are there any fine TELESCOPIC OBJECTS in this constellation?

A. There is a *singular nebula* in Sobieski's Shield. It was discovered by Sir John Herschel, who describes it as containing two small stars of a gray color.

Fig. 150.

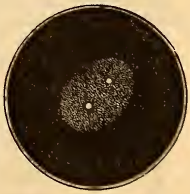
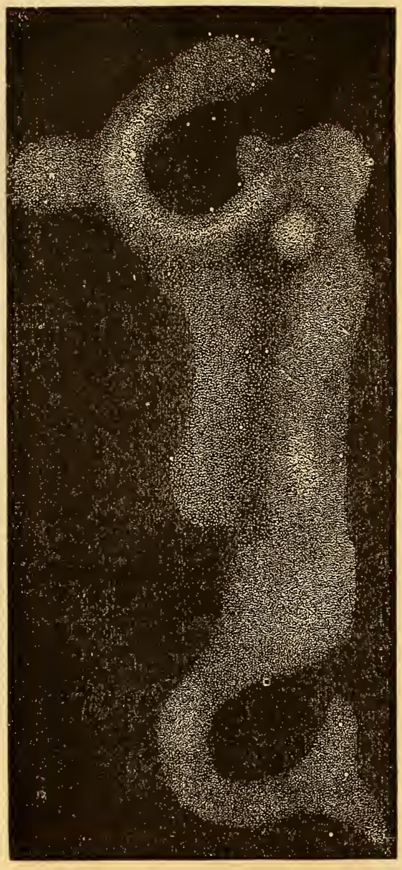


Fig. 150 is a representation of this remarkable object.

Q. What other wonderful TELESCOPIC OBJECT does this constellation contain?

A. There is *one nebula* in this constellation, immediately below

Fig. 151.



the Shield, which is in the form of a *horse-shoe;* but when viewed with high magnifying power, it presents a different appearance.

Sir William Herschel estimated this nebula to be nine hundred times farther from us than Sirius. In some parts of its vicinity he observed *five hundred and eighty-eight* stars in his telescope at one time; and he counted *two hundred and fifty-eight thousand* in a space 10° long and $2\frac{1}{2}$° wide.

The annexed figure is copied from Sir John Herschel's observations at the Cape of Good Hope, as it appeared through his telescope.

Such is the wondrous arrangement of the celestial bodies! Suns upon suns are thickly scattered throughout illimitable space, all obeying certain laws which were established by the fiat of the Great Eternal, for the preservation of that stability and unbroken harmony which characterizes all his works.

"A mighty maze, but not without
a plan."—POPE.

ANTINOUS.

Q. Where is Antinous SITUATED?

A. East of *Taurus Poniatowski* and *Scutum Sobieski*, on the *equinoctial.*

Q. How is Antinous REPRESENTED?

A. By the figure of a *youth* with a *bow* and *arrows* in his hand.

Q. Are there any stars of the FIRST MAGNITUDE in this constellation?

A. There are *not;* there are none *above* the *third* magnitude.

By reference to the globe or map, this constellation may readily be found, though the stars of which it is composed are not at all conspicuous.

AQUILA.

Q. What constellation is that immediately NORTH of Antinous?

A. *Aquila.*

Q. Are there any BRIGHT STARS in Aquila?

A. Yes; there is a row of *three bright stars* in this constellation; the middle one of the three is of the *first* magnitude.

Q. What is this star of the first magnitude CALLED?

A. It is called *α* (Alpha) Aquilæ, or *Altair.*

The Arabians called this star *el-tâir,* "the flying eagle;" whence the name Altair.

Q. How is the row of three stars, of which Altair is the middle one, SITUATED?

A. In a line *south-east* from *Wega*, in Lyra.

Q. What is the name of the NORTHERNMOST of these three stars?

A. *Tarazed*, or *γ* (Gamma) Aquilæ.

Sháhin-tara-zed, "the star-striking falcon," was a name applied to the constellation by the Persians; but now the latter portion of the name is given to the northern of the three bright stars, also known as γ (Gamma) Aquilæ.

Q. What is the name of the SOUTHERNMOST star in the row?

A. *Alshain*, or *β* (Beta) Aquilæ.

Alshain is a corruption of the Persian word *al-sháhin,* "the falcon."

Q. What TWO bright stars are in the tail of the Eagle?

A. They are called ε (Epsilon) and ζ (Zeta) Aquilæ; ζ (Zeta) is also called *Deneb-el-Okáb.*

Deneb means "the tail," and el-Okáb, "the eagle;" therefore ζ (Zeta) is called Deneb-el-Okáb, because it is situated in the tail of the Eagle.

Q. How may these two stars be IDENTIFIED?

A. They are about *eighteen* degrees due south of *β* (Beta) and *γ* (Gamma) Lyræ.

SAGITTA.

Q. Where is the constellation Sagitta to be FOUND?

A. It consists of a *few small stars* situated about *ten degrees* north of Altair, and is represented by the figure of an *arrow.*

VULPECULA ET ANSER.

Q. How is this constellation REPRESENTED?

A. By a *fox*, with his head towards the west, and having a *goose* in his mouth.

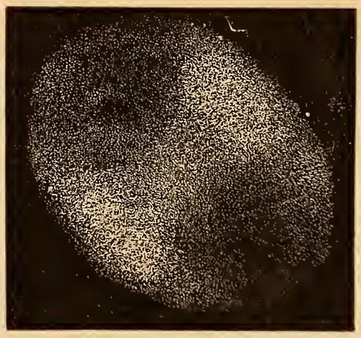
Q. Are there any BRIGHT STARS in this constellation?

A. There is *one* of the *third* magnitude in the head of the fox, *eighteen degrees* north of Altair; the other stars in this constellation are of the fifth and sixth magnitudes.

Q. Is there any REMARKABLE TELESCOPIC object in this constellation?

A. About *fourteen degrees* north of Altair is an *elliptical nebula*, the brightest part of which somewhat resembles a dumb-bell in shape.

Fig. 152.



The above figure represents this object, as seen through Sir John Herschel's telescope.

Fig. 153 is the appearance it assumed when viewed through Lord Rosse's great telescope. The bright central part is resolved into stars, and a fringy appearance is visible on one side.

Fig. 153.

CYGNUS.

Q. What constellation is that which lies EAST of LYRA and NORTH of VULPECULA?

A. *Cygnus.*

Q. Are there any BRIGHT STARS in this constellation?

A. It is commonly known by *five* bright stars situated so as to form a *cross*. This cross lies in the Milky Way, about *twenty degrees east* of Lyra.

Q. What is the BRIGHTEST STAR in the cross?

A. *Arided*, *Deneb*, or *α* (Alpha) *Cygni*, is of the second magnitude, and is situated at the top of the cross, or in the tail of the Swan.

Q. About ten degrees west of Arided is a bright star of the THIRD magnitude: what STAR is this?

A. It is δ (Delta) Cygni, and forms the *western extremity* of the cross-piece. This star δ (Delta) is found to be double when viewed through the telescope, one of the stars appearing of a *bright yellow*, the other of a *brilliant sea-green*.

Q. How can the OTHER stars in the cross be DISTINGUISHED?

A. To the south-east of δ (Delta) is a bright star, which, with Arided, forms a triangle. The name of this star is γ (Gamma) Cygni, or *Sad'r*. Imagine a line drawn from δ, (Delta,) at the western extremity of the cross-piece, through Sad'r, and extended as far again; this line would touch the *eastern extremity* of the cross-piece, in the star λ, (Lambda;) then draw a line from Arided at the top, through Sad'r, and extend it twice as far, and you touch the star in the foot of the cross, which is called *Albireo*, or β (Beta) Cygni.

Q How is this constellation REPRESENTED on the globes and maps?

A. By a *swan* flying down the Milky Way, the foot of the cross being on the bird's bill, and the extremities of the cross-piece representing its wings. The other stars of Cygnus are readily traced by a map.

Q. What REMARKABLE star is there in Cygnus?

A. A *small star* marked 61 on the globes, and known as 61 Cygni, situated about 8° south-east of Arided.

Q. For what is this star REMARKABLE?

A. It is supposed to be one of the nearest stars to our system, and was the first which was observed to have *parallax.*

Q. Is 61 Cygni a DOUBLE star?

A. It is; and one of them revolves round the other in a period of more than *five hundred years.*

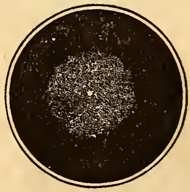
Q. Why is 61 Cygni considered as being one of the NEAREST fixed stars?

A. Because it appears to have an extremely *rapid* and *uniform* motion *through space* towards some determinate though unknown region. This apparently rapid motion may be, in part, owing to the real motion of our solar system in space in an opposite direction; though, according to Sir William Herschel, we are *approaching* that quarter of the heavens.

Q. What TELESCOPIC OBJECT is there in the constellation Cygnus?

A. A very singular nebula on the tip of the western wing.

Fig. 154.



The figure represents this object, which Herschel thinks appears to constitute the connecting link between planetary nebulæ and nebulous stars.

CEPHEUS.

Q. How is the constellation Cepheus REPRESENTED?

A. By the figure of a *king*, with a *crown* on his head and a *sceptre* in his hand. One foot rests on the *solstitial colure;* the other is within a degree or two of the *Polar Star.*

Q. What is the PRINCIPAL STAR in this constellation?

A. *Alderamin*, a star of the third magnitude, in the western shoulder.

Q. How may Alderamin be DESIGNATED?

A. A line drawn from *Polaris* (the Pole Star) to *Arided*, in Cygnus, will pass four degrees to the *west* of Alderamin, which lies a little more than midway between the pole and Arided.

Q. Describe the OTHER STARS in this constellation.

A. About *eight degrees* north of Alderamin is β, (Beta,) or *Alphirk*, in the side of Cepheus; and fourteen degrees to the north-east of Alphirk is γ, (Gamma,) or *Errai*. In the head are *three* small stars forming a *triangle*, one of which is *variable*.

Q. Why is γ, (Gamma,) or Errai, worthy of NOTE?

A. Because in *two thousand three hundred and sixty years* hence it will be the *Pole Star*.

Q. What remarkable TELESCOPIC OBJECT is there in Cepheus?

A. A brilliant cluster *sixteen degrees* due south of *Errai*, in the form of a triangle, with a small orange-colored star in its vertex.

This cluster is described as a mass of very small stars blended with nebulous matter.

Q. When is Cepheus on the MERIDIAN?

A. About *nine* in the evening on the 10th of *October*.

LACERTA.

Q. What constellation, south of Cepheus, is on the meridian at the same time?

A. *Lacerta*.

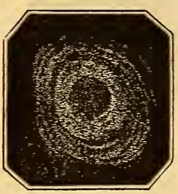
Q. Are there any CONSPICUOUS STARS in Lacerta?

A. It is composed of a few small stars, but none are above the *fifth magnitude*.

Q. Is there any remarkable TELESCOPIC OBJECT in this constellation?

A. About 30° west of Almach, in the foot of Andromeda, is a species of spiral nebula with a dark centre.

Fig. 155.



The annexed drawing is taken from one made by Lord Rosse.

HONORES FREDERICI.

Q. Where is this constellation SITUATED?

A. Immediately *east of Lacerta*. It contains but a few small stars.

This constellation is not generally recognised by astronomers, it having, by some, been suppressed.

DELPHINUS.

Q. What CONSTELLATION is that which comes to the meridian about the 15th of September?

A. *Delphinus*.

This constellation is commonly known by the name of *Job's Coffin*.

Q. What are the PRINCIPAL stars in Delphinus?

A. They are called α, (Alpha,) β, (Beta,) γ, (Gamma,) and δ, (Delta,) and are situated so as to form a diamond. These stars are on the meridian at the same time as *Arided* in *Cygnus.* Immediately below these, to the south-west, is ε, (Epsilon,) in the Dolphin's tail.

EQUULEUS.

Q. Where is the constellation Equuleus SITUATED?

A. South-east of *Delphinus*, near the head of *Aquarius.*

Q. How is this constellation DISTINGUISHED?

A. By a trapezium, sometimes called *Kitalpha*, consisting of *four stars* of the fourth magnitude, α, (Alpha,) β, (Beta,) γ, (Gamma,) and δ, (Delta.)

Kitalpha is from the Arabic *kit-ât al-faras'*, "part of a horse."

PEGASUS.

Q. How is the constellation Pegasus DELINEATED?

A. By the *head and half the body of a horse*, with wings attached.

Q. What are the most CONSPICUOUS stars in Pegasus?

A. There are four bright stars, from *twelve* to *seventeen* degrees apart, which form a quadrilateral figure, familiarly known as the *Square of Pegasus.*

Q. Where are these stars SITUATED?

A. *Markab* is in the shoulder of the Horse; twelve degrees north of it is *Scheat*, on the fore leg; about fifteen degrees east of Scheat is *Alpheratz*, which is situated on the equinoctial colure; fifteen degrees south of Alpheratz is *Algenib.* These four stars form the Square of Pegasus.

Q. There is a bright star in the Horse's mouth: what is its name?

A. It is called *Enif.*

From the Arabic *enf*, "the nose."

Q. Is there any remarkable TELESCOPIC OBJECT in Pegasus?

A. There is a globular cluster between the mouths of Pegasus and Equuleus, which Sir William Herschel estimated to be *two hundred and forty-three* times *farther* from us than Sirius.

Fig. 156.

The cluster in the figure is at an almost infinite distance beyond the small telescopic stars on each side of it.

ANDROMEDA.

Q. What is the NAME of that constellation east of Pegasus which comes to the meridian about nine o'clock in the evening on the 20th of November?

A. *Andromeda.*

Q. How is Andromeda REPRESENTED on the globes and maps?

A. By a *female figure* with *chains* on her wrists.

Q. What is the PRINCIPAL STAR in the constellation Andromeda?

A. *Alpheratz*, or *α* (Alpha) Andromeda.

Q. How may Alpheratz be FOUND?

A. It is situated *fifteen degrees* north of Algenib, on the equinoctial colure, and forms the *north-eastern* star in the *Square of Pegasus.*

Fig. 157.

Q. How may the other BRIGHT stars in this constellation be designated?

A. About fifteen degrees a little to the north-east of Alpheratz is the bright star *β* (Beta) Andromeda, or *Mirach;* and a line drawn from Alpheratz, through Mirach, ten degrees farther, will reach *Almach*, or *γ* (Gamma) Andromeda.

Q. Are there any remarkable TELESCOPIC OBJECTS in this constellation?

A. Besides the beautiful nebula represented in *fig.* 122, there is an *elliptical nebula* in the right foot of Andromeda, the centre of which appears *black*, and at each extremity of this black centre is a small star.

Sir John Herschel notes this nebula in his catalogue as "*a wonderful object.*" This nebula, discovered by Miss Caroline Herschel, is supposed to be of enormous dimensions. Its form is that of a flattened ring seen edgeways, and is placed at an inconceivable distance from us. It consists, probably, of *myriads* of solar systems, which, taken together, are but a point in the universe.

"Yet what is this, which to the astonished mind
Seems measureless, and which the baffled thought
Confounds? A span, a point, in those domains
Which the keen eye can traverse."—WARE

CASSIOPEIA.

Q. What constellation is that situated due NORTH of Andromeda?

A. *Cassiopeia.*

Q. How is Cassiopeia REPRESENTED on the maps?

A. By a *female* seated in a chair, with her feet resting on the Arctic Circle.

Q. How is the constellation Cassiopeia SITUATED?

A. It is situated on the *opposite side* of the pole from the Great Bear.

Q. What FORM do the principal stars in this constellation assume, when taken COLLECTIVELY?

A. They are disposed so as to form the *letter* W.

Q. How are these principal stars in Cassiopeia to be FOUND?

A. About half-way between Alpheratz, in the head of Andromeda, and the Pole Star, is *Caph.*

Q. What remarkable SITUATION has the star Caph?

A. It is situated on the *equinoctial colure*, and is on the same side of the *true pole* as the Pole Star.

As the Pole Star is not situated *exactly* at the true celestial pole, but within 1° 32′ 56″, or about 1½°, of it, on the same side as Caph, the position of the Pole Star with regard to the pole may be known by observing the star Caph.

Q. What is the NEXT bright star east of Caph?

A. *Shedir:* it is situated about *five* degrees south-east of Caph. To the north-east of Shedir, and six degrees east of Caph, is γ (Gamma) Cassiopeiæ; a little to the south-east of γ, (Gamma,) and nearly ten degrees east of Caph, is δ (Delta) Cassiopeiæ; the fifth star, which forms the upper point of the W, is ε, (Epsilon,) in the Lady's ankle.

Shedir is so called from *Al-sadr,* "the breast," because it is situated on the breast of Cassiopeia.

Q. Has any thing been discovered with respect to any of these five stars?

A. Yes; *Shedir* is found to be *variable*, its period from least to greatest brightness being about *two hundred days;* γ (Gamma) is also supposed to be periodically variable.

Q. What REMARKABLE OBJECT once appeared in this constellation?

A. A *new star* suddenly burst forth in full splendor.

Q. Where was the new star SITUATED?

A. Near the *eastern foot* of Cassiopeia.

Q. WHEN did this star appear?

A. In *November*, 1572. (*See Note* 50.)

Q. What APPEARANCE did this star assume during the time it was visible?

A. At first it was *white*, then *yellow*, then *red*, and finally a *blueish gray.*

Q. How LONG was it visible?

A. *Sixteen months;* that is, from November, 1572, to March, 1574.

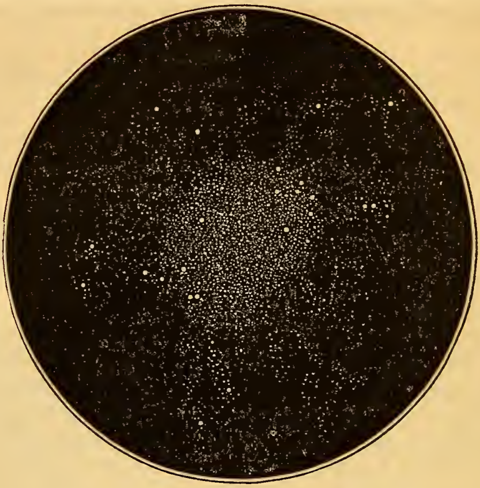
Q. By what GREAT ASTRONOMER was this star particularly observed?

A. By *Tycho Brahé.*

Q. Are there any remarkable TELESCOPIC objects in Cassiopeia?

A. About *three degrees* south-west of Caph is a *magnificent cluster* of stars, which was discovered by Miss Caroline Herschel, in 1783.

Fig. 158.



This assemblage of stars, as represented in the figure, is only a *small* portion of a vast region of inexpressible splendor extending some distance around it.

"Some sequestered star
That rolls in its Creator's beams afar,
Unseen by man; till telescopic eye,
Sounding the blue abysses of the sky,
Draws forth its hidden beauty into light,
And adds a jewel to the crown of night."

TRIANGULUM.

Q. Where is Triangulum SITUATED?

A. It is a little to the *south-east* of *Andromeda*, and comes to the meridian with Almach.

Q. How is this constellation REPRESENTED?

A. By a figure of a *triangle.*

Triangulum is one of the old forty-eight constellations, and is supposed to have been formed in imitation of the Greek capital letter Δ, (*Delta.*) Hevelius formed a second triangle, which he called *Triangulum Minus;* but it is no longer continued in some maps.

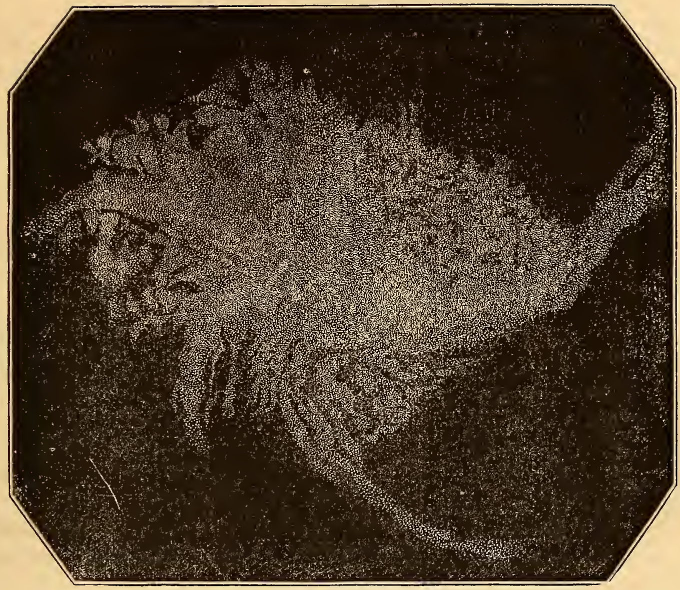
Q. Are there any LARGE stars in Triangulum?

A. No. The principal star is of the *third* magnitude, and is situated about seven degrees north-west of Arietis.

Q. Are there any TELESCOPIC objects in Triangulum?

A. There is a remarkable nebula about *ten degrees* west of the principal star in Triangulum.

Fig. 159.



This wonderful object is represented as it appears in Lord Rosse's great telescope. It was supposed by Sir William Herschel to be of the three hundred and forty-fourth order; that is, three hundred and forty-four times the distance of Sirius from the Earth; which would be the immense sum of nearly *seventeen thousand billions* of miles from our planet.

MUSCA.

Q. Where is MUSCA?

A. It is a small new constellation, directly north of Aries. It contains *no very bright stars;* the principal are three of the third and fourth magnitudes.

This constellation was formed by Bartschius, the son-in-law of Kepler, for which reason Hevelius retained it in his catalogue.

PERSEUS ET CAPUT MEDUSA.

Q. Where is Perseus SITUATED? and how is it REPRESENTED?

A. It is situated *east* of Andromeda and Cassiopeia, and *north* of Aries; it is represented by the figure of a *man* with the *head of Medusa* in one hand, and a *sword* in the other.

The head of Medusa is covered with twining snakes instead of hair, and is sometimes noticed as a separate constellation, but astronomers usually unite it with Perseus.

Q. When does Perseus come to the MERIDIAN?

A. It comes to the meridian at *nine* o'clock in the evening, about the *twentieth of December.*

Q. Where is the PRINCIPAL star in this constellation?

A. About *fourteen degrees* north-east of Almach is *Algenib*, or *α* (Alpha) Persei, a star of the second magnitude, in Perseus's side.

This star was formerly called *Mirfak*.

Q. Where is there ANOTHER bright star in this constellation?

A. In the *head of Medusa*. It is called *Algol*, or *β* (Beta) Persei.

Q. Is there any thing REMARKABLE about Algol.

A. It is a *variable* star; at its brightest it is of the *second* magnitude, after which it changes to a star of the *fourth* magnitude.

Q. What TIME does it occupy in these changes?

A. About *two days and twenty hours.*

It varies from the second to the fourth magnitude in three hours and a half, and then increases in brightness up to the second magnitude in the same time; and for the remainder of the period remains at the brightness of the second magnitude.

Q. Where is Algol SITUATED?

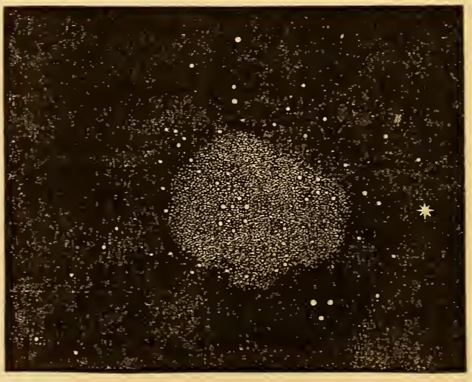
A. About *nine degrees south-west* of Algenib.

The other stars of this constellation can easily be found by consulting a map or globe.

Q. What noted TELESCOPIC objects are there in this constellation?

A. On the *handle of Perseus's sword* is a magnificent cluster of stars, which emits a peculiarly splendid light when seen through the telescope.

Fig. 160.



The figure above represents this gorgeous group. Immediately following it is another splendid cluster of almost equal brilliancy.

TARANDUS.

Q. Where may Tarandus be FOUND?

A. It is a small constellation represented by a *reindeer*, directly *north* of Cassiopeia, and *east of* Cepheus. It contains no conspicuous stars.

AURIGA.

Q. What constellation is that situated NORTH of the Bull's horns and EAST of Perseus?

A. *Auriga*, or the *Charioteer.*

Q. What is the CHIEF star in Auriga?

A. *Capella*, situated about 30° north-east of *Aldebaran*, and the same distance north-west of *Castor* in Gemini.

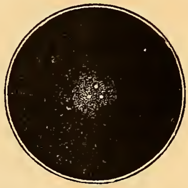
Q. What star is that on the eastern SHOULDER of Auriga?

A. *Menkalinan*, or β (Beta) Aurigæ. It is situated about *eight* degrees *east* of Capella, and is of the second magnitude.

Q. Are there any TELESCOPIC OBJECTS in Auriga worthy of note?

A. There is one situated in right ascension 5*h.* 20*m.* 51*s.*, and declination 34° 6′ north.

Fig. 161.



It will be seen by reference to the figure that in the centre of this nebula is a small triangle, consisting of three minute stars surrounded by a nebula.

CAMELOPARDALUS.

Q. What constellation is that situated NORTH of PERSEUS and AURIGA?

A. *Camelopardalus.* This constellation occupies that vast space between the Pole Star, Perseus, and Auriga.

It was formed by Bartschius, and was only retained by Hevelius, when forming his new catalogue, on account of its having been introduced by Kepler's son-in-law.

Q. Does Camelopardalus contain any BRIGHT stars?

A. It contains no star above the *fifth magnitude.*

LYNX.

Q. Where is the constellation of the Lynx SITUATED?

A. It lies between the *Great Bear* and *Auriga*, and north of *Gemini* and *Cancer.*

Q. Does it contain any CONSPICUOUS stars?

A. It does *not.*

This constellation is one of the new ones formed by Hevelius.

TELESCOPIUM HERSCHELII.

Q. Where is Telescopium Herschelii to be FOUND?

A. It is a small constellation situated between the Lynx and Gemini. It contains no conspicuous stars.

This constellation was formed by Bode, in honor of the discoveries of Sir William Herschel.

SECTION III.

Southern Constellations.

Q. What are the SOUTHERN constellations?

A. Those constellations situated *south* of the *zodiac.*

MONOCEROS.

Q. How is Monoceros REPRESENTED?

A. By a fabulous animal, somewhat resembling a horse, with one horn in the forehead.

Q. How is Monoceros SITUATED?

A. It lies *east* of Orion, the equinoctial passing through its *centre.*

Q. Are there any stars of the FIRST MAGNITUDE in this constellation?

A. No; there are none above the fourth magnitude.

ORION.

Q. Where is the beautiful constellation ORION situated?

A. It is situated on the equinoctial, due south of the *horns of Taurus,* and west of the *solstitial colure.*

Q. When is the constellation Orion to be seen on the meridian in the EVENING?

A. About the *twenty-fifth of January,* at 9 o'clock in the evening, the centre of the constellation will be seen on the meridian.

Fig. 162.

Fig. 162 represents the constellation Orion. The right side of the picture is the west, and the left-hand side the east. The star marked α is Betelgeuse, on the east shoulder; on the west shoulder is Bellatrix, marked γ. The three stars in his belt are δ, ϵ, ζ; and

the one in his western foot, β, is Rigel. A small triangle forms the face, the northern star of which is λ. The semicircle on the west side of the picture are the stars which form the lion's skin.

Q. Are there many BRIGHT stars in Orion?

A. There is *one* on each shoulder; *three* form his belt; and there is *one* in his foot.

Q. How is Orion REPRESENTED?

A. By the figure of a man resting on one knee, with a *lion's skin* in one hand and a *club* in the other, with which he is beating Taurus.

Q. What is the PRINCIPAL star in this constellation?

A. Betelgeuse, or α (*Alpha*) Orionis, a star of the first magnitude, in Orion's eastern shoulder.

Q. How may Betelgeuse be INDENTIFIED?

A. By running an imaginary line through the stars in the *end* of the *Bull's horns*, and extending it about *twelve degrees*.

Q. What is the name of the star in his WESTERN SHOULDER?

A. It is called γ (Gamma) Orionis, or *Bellatrix*, and is nearly 8° west of Betelgeuse.

Q. What is the name of the bright star in Orion's western FOOT?

A. Rigel, or β (*Beta*) Orionis. It is a star of the first magnitude, and with good telescopes appears *double*.

Rigel derives its name from the Arabic Rijl-al-jauza, "the giant's leg."

Q. What OTHER well-known stars are there in this constellation?

A. The *three* in his *girdle*, situated about midway between Betelgeuse and Rigel.

Q. What Greek letters are they known by?

A. They are known as δ, (*Delta*,) ε, (*Epsilon*,) and ζ (*Zeta*) Orionis; which means that they are the δ, ε, and ζ of the constellation Orion.

By seamen the three stars in Orion's belt were called the *Golden Yard.* They are also called *Jacob's Staff*, the *Three Kings*, the *Rake, Our Lady's Wand*, the *Ell and Yard*, &c. A line drawn through the three stars in the belt, and extended to the north-west, will reach the Hyades and Pleiades.

Q. There are three stars which of themselves form a small triangle, and which taken collectively form a triangle with Betelgeuse and Bellatrix, (the two stars on his shoulders:) in what part of the constellation are these three small stars situated.

A. They are situated on his *face.*

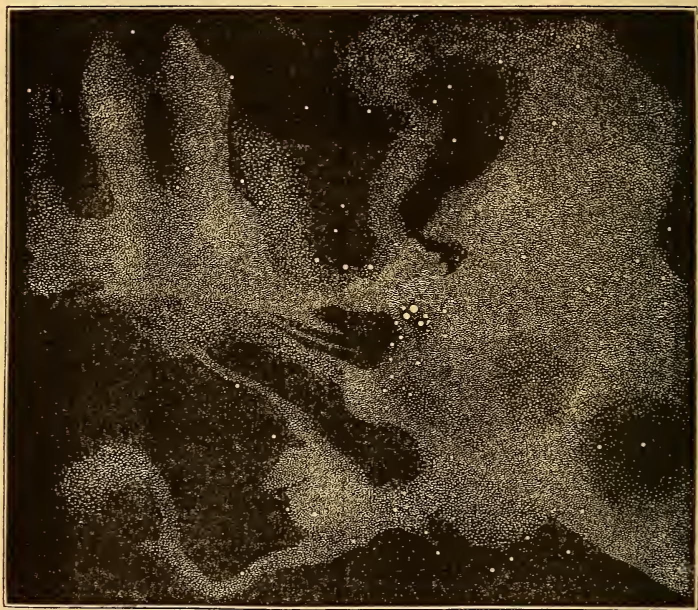
Q. What REMARKABLE STAR is that situated just below the belt of Orion, about one degree south-west of ζ, (Zeta.)

A. It is ς (*Sigma*) Orionis, a multiple star, which the telescope shows to be composed of *ten* members.

Q. What remarkable TELESCOPIC OBJECT is there in the sword-handle of Orion?

A. Near the star marked ϕ (*Phi*) is a wonderful nebula, consisting of hundreds of stars, which are surrounded by a great nebulosity which no telescopes have yet resolved into stars.

Fig. 163.



This nebula is known as the Fish's Mouth, to which it is thought to bear some resemblance. Sir John Herschel has delineated it,* and given a catalogue of 150 of the stars contained in it, together with its nebulous branches and convolutions, which, owing to the small size of our figure, cannot be fully shown. In large telescopes, to use Sir John Herschel's own words, it has the appearance of a "curling liquid; or a surface strewn over with flocks of wool; or the breaking up of a mackerel sky." If, says the same author, the parallax of this nebula be no greater than that of the stars, its breadth cannot be less than one hundred times that of the Earth's orbit; that is, it must equal nineteen thousand millions of miles in diameter. But if, as is still more probable, this nebula be at a vast distance beyond the most distant stars, its magnitude must be inconceivably great.

"Orion's beams! Orion's beams!
His star-gemm'd belt, and shining blade,
His isles of light, his silvery streams,
And gloomy gulfs of mystic shade."—Manilius.

CANIS MINOR.

Q. How is the constellation Canis Minor REPRESENTED?

A. It is represented by a *small dog* standing on, or just above, the back of Monoceros, with its head towards the west.

Q. Are there any BRIGHT stars in Canis Minor?

A. There are *two:* one of the first magnitude, called *Procyon,*

* See Observations at the Cape of Good Hope, p. 25, and Plate VIII.

is situated in the heart of Canis Minor; the other, called *Gomeisa*, in his neck, is of the third magnitude.

LEPUS.

Q. What constellation is that immediately SOUTH of Orion?

A. *Lepus*, or the Hare.

Q. Are there any LARGE stars in this constellation?

A. The largest is one of the *third* magnitude. There are four small stars in this constellation, which form a four-sided figure.

SCEPTRUM BRANDENBURGIUM.

Q. Where is the constellation Sceptrum Brandenburgium SITUATED?

A. It is composed of a few scattered stars, *west* of *Lepus*.

This constellation was formed in 1668, by Kirch, a German astronomer.

CANIS MAJOR.

Q. How is Canis Major REPRESENTED?

A. By the figure of a dog resting on his hind feet, holding up his paws. His face is turned towards the west.

The Tropic of Capricorn passes through the middle of this constellation.

Q. When does Canis Major come to the MERIDIAN?

A. About an *hour after Orion*, or about 10 o'clock in the evening on the 25th of January.

Q. What is the PRINCIPAL STAR in this constellation?

A. *Sirius;* it is situated in the nose of Canis Major, and forms an equilateral triangle with Procyon in Canis Minor, and Betelgeuse in Orion's shoulder.

Sirius is also known by the names of *Canicula* and the *Dog Star*.

Q. Is Sirius a star of the FIRST magnitude?

A. Yes; it is the *brightest star* in the heavens.

According to Sir John Herschel's experiments, the light of Sirius is found to be equal to three hundred and twenty-four times that of a star of the sixth magnitude, which is the smallest heavenly body visible to the naked eye. Dr. Wollaston estimated the light of Sirius to be less than the *twenty thousand millionth* part of the Sun's light! But owing to the immense distance of this star from us, he concludes that its splendor, to an eye placed at 95,000,000 of miles from it, must be nearly equal to *fourteen* of our suns!!

COLUMBA.

Q. Where is Columba SITUATED?

A. *South* of Lepus and *west* of Canis Major and Argo.

Q. How is it REPRESENTED?

A. By a *dove*, with an olive-branch in its mouth.

This constellation was introduced by Royer, in 1697.

Q. Describe the STARS in Columba?

A. The principal star is *a*, (*Alpha*,) in the middle of the Dove's back. It is situated about *twenty-two dejrees* south-west of Sirius,

and comes to the meridian *one hour* before it. β (Beta) and γ (Gamma) are two stars in the Dove's breast, south-east of α, (Alpha.) There are no remarkable stars in this constellation.

OFFICINA TYPOGRAPHIA.

Q. Where is the constellation Officina Typographia SITUATED?

A. Directly *east* of Canis Major, and *south* of Monoceros. It is one of the new constellations formed by Bode.

Q. Does it contain any stars of the FIRST or SECOND magnitude?

A. No; it is composed of *small stars*, and contains some rich clusters not visible to the naked eye.

CELA SCULPTORIA.

Q. Where may CELA SCULPTORIA, or PRAXITELES, be found?

A. It comes to the meridian about *two hours before* Sirius; and is on the meridian *fifty-five degrees* south of Aldebaran.

It is one of the modern constellations, formed by Lacaille.

EQUULEUS PICTORIUS.

Q. DESCRIBE the constellation Equuleus Pictorius.

A. It is one of the *modern* constellations, formed by Lacaille; it is situated south of Columba, and *fifty-five* degrees south declination. The solstitial colure passes through it. It contains no conspicuous stars.

ARGO NAVIS.

Q. Where is the constellation Argo Navis SITUATED? and when does it come to the MERIDIAN?

A. It is situated south-east of *Monoceros* and *Officina*, and east of *Columba.* The centre of this constellation comes to the meridian at 9 o'clock in the evening on the first of March.

Q. Is Argo Navis a LARGE constellation?

A. It is; and therefore astronomers divide it into four parts; namely, *Argo Navis*, or the *Hull; Carina*, or the *Keel; Puppa*, or the *Stern;* and *Velis*, or the *Sails.*

Q. Is this constellation visible in the latitude of NEW YORK?

A. Only the *northern part* of it is visible in that latitude; but to those living under the Tropic of Cancer the whole constellation is above the horizon.

Q. Are there any BRIGHT stars in Argo?

A. There is in this constellation a magnificent star of the *first magnitude*, called *Canopus*, which comes to the meridian fifteen minutes before Sirius.

To an inhabitant living at 37° north latitude, Canopus will just graze the southern horizon at 9 o'clock in the evening on the 5th of February. Canopus is situated about 53° south of the equator.

Q. Is Canopus the BRIGHTEST star in the firmament?

A. It is not as bright as Sirius, but it is a star of the *first magnitude.*

Q. Is there any OTHER star of the first magnitude in the constellation Argo?

A. Yes; a star marked β, (*Beta*,) about *twenty-five degrees* south-east of Canopus, is of the first magnitude.

This star, called also *Miaplacidus,* is sometimes reckoned to be in the constellation Robur Caroli.

Q. Name the OTHER principal stars in Argo.

A. About 24° north-west from β (*Beta*) is γ, (Gamma,) in the middle of the Ship. It forms a right-angled triangle with Canopus and β. Seven degrees north-west of γ is ζ, (*Zeta*,) or *Noas.* This star is in a line with β and γ. There are many other stars of the third, fourth, and fifth magnitudes in this constellation.

Q. Is there any PECULIARITY about the star η, (Eta?)

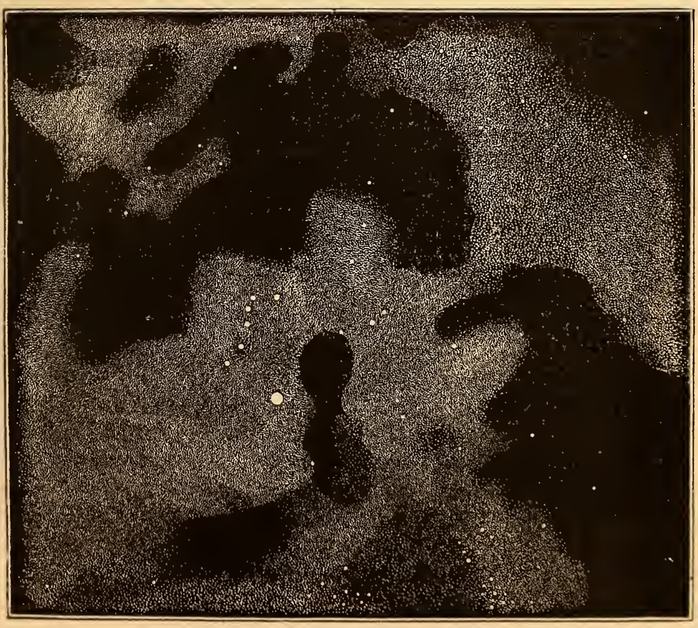
A. Yes; it is known to *vary* in brightness from the brilliancy of Sirius to a star of the *fourth magnitude.*

The star η (*Eta*) is situated about 15° north-east of Miaplacidus.

Q. Is there any remarkable TELESCOPIC object in this constellation?

A. The star η (*Eta*) is situated in a vast *stratum of stars* and *nebulæ*, which renders it one of the most interesting objects of the southern hemisphere.

Fig. 164.



The great nebula surrounding η Argus is found to consist of from 2000 to 6000 stars, which have been revealed by the telescope, besides large nebulous tracts which defy the powers of the best glasses which have ever been manufactured. One of the areas which Sir John Herschel examined was estimated to contain more than *five thousand stars in a square degree.*

Q. Is this nebula near the MILKY WAY?

A. It is seen *through* the Milky Way, but is computed to be at an *infinite distance beyond it.*

Fig. 165.

Sir John Herschel, in speaking of this nebula, says—"It is impossible for any one, with the least spark of astronomical enthusiasm about him, to pass soberly in review that portion of the southern sky; such are the variety and interest of the objects he will encounter, and such the dazzling richness of the starry ground on which they are represented to his gaze." The same author has made a catalogue of 1216 of the principal stars in this wonderful nebula.

Q. What OTHER telescopic object is to be found in Argo Navis?

A. Near η (Eta) Argus there is a remarkable sidereal object like a comet, or curved wisp of light, with a double star in the head of it. *Fig.* 165 is a representation of it, as seen by Sir John Herschel.

PYXIS NAUTICA.

Q. Where is Pyxis Nautica SITUATED in the heavens?

A. Immediately *north* of Argo.

Q. Is this a LARGE constellation?

A. No; it is one of the *new* constellations formed by Lacaille, and contains no *conspicuous* stars.

PISCES VOLANS.

Q. How is this constellation REPRESENTED?

A. By a fish, with *long fins* expanded.

Q. Where is it SITUATED?

A. Directly *south* of Argo Navis. There are *no* bright stars in Pisces Volans.

ROBUR CAROLI.

Q. Where is Robur Caroli SITUATED?

A. It is *east* of Argo, in the Milky Way. There is a bright star in Robur Caroli called Miaplacidus, though some astronomers consider it as belonging to Argo Navis, and distinguish it by the letter β.

This constellation was formed by Halley.

HYDRA.

Q. How is Hydra REPRESENTED on maps and globes?

A. As a huge *snake*, whose head is south of *Cancer* and points to the west; its body then crosses the equinoctial, and, with various circumlocutions, passes to the eastward, south of *Leo*, crosses the equinoctial colure south of *Virgo* and *Libra*, and its tail terminates at the claws of *Scorpio*.

Q. Are there any BRIGHT stars in Hydra?

A. There is a star of the *second magnitude* in this constellation, called *Cor Hydra*, "the Serpent's Heart;" this star is also called *α* (Alpha) Hydræ, or *Alphard*.

This star makes a right angle with Procyon in Canis Minor, and Regulus in Leo. There are other stars in this constellation, but none of them conspicuous.

SEXTANS.

Q. How is Sextans REPRESENTED on globes and maps?

A. By the figure of a sextant, which is placed between Hydra and Leo. It contains no conspicuous stars.

This constellation was formed by Hevelius, to commemorate the sextant which Tycho Brahé used at his observatory at Uraniburg, and which was subsequently destroyed by fire in his house in Dantzic, in September, 1679.

FELIS.

Q. Where is Felis to be FOUND?

A. It lies on the *meridian* with *Regulus*, the principal star in Leo, and is *south* of Hydra.

This constellation, represented by a cat crouching, was introduced by Bode; it contains no conspicuous stars.

ANTLIA PNEUMATICA.

Q. How is Antlia Pneumatica REPRESENTED?

A. It is represented by the figure of an *air-pump*.

Q. Where is it SITUATED?

A. Between *Felis* and *Robur Caroli*. It contains no large stars.

This constellation was introduced by Lacaille.

CRATER.

Q. Where is the constellation Crater SITUATED?

A. It is situated about the middle of Hydra, of which it is by some considered the same constellation.

Q. Describe the PRINCIPAL stars in Crater.

A. There are *six* stars of the fourth magnitude, which, taken together, form a beautiful *crescent*, which is open to the north-west. This crescent comes to the meridian about twenty-five minutes before Denebola, in the tail of Leo. It is one of the old forty-eight constellations.

CORVUS.

Q. Where is Corvus SITUATED?

A. *South* of Virgo and *east* of Crater. The equinoctial colure runs through this constellation.

This is one of the old forty-eight constellations.

Q. What is the PRINCIPAL star in Corvus?

A. *Algorab*, on the wing. It lies *fifteen degrees* south-west of Spica in Virgo: it makes an exact equilateral triangle with Spica and that noted star, γ (Gamma) Virginis.

Algorab is derived from the Arabic *Al-ghoráb*, "the raven."

CENTAURUS.

Q. How is Centaurus REPRESENTED?

A. By a figure *half man* and *half horse*, the middle of the man being united to the shoulders of the horse. The man holds a *spear* in his right hand, with which he is piercing a *wolf*, which he holds in his left.

Q. Where is Centaurus SITUATED?

A. The centre of Centaurus is to be found about *fifty degrees* south of Virgo. Hydra and Corvus lie between Virgo and Centaurus.

Q. What is the PRINCIPAL star in Centaurus?

A. A star known as α (Alpha) Centauri is one of the *brightest* and one of the *most remarkable* stars in the southern hemisphere.

Q. Where is α (Alpha) Centauri SITUATED?

A. In the *Milky Way*, sixty degrees south of the equator, and comes to the meridian a few minutes after Arcturus in the constellation Boötes.

Q. For what is α (Alpha) Centauri REMARKABLE?

A. It is remarkable as being the *nearest to our system* of any star with which we are acquainted.

The star α (Alpha) Centauri is computed to be about *twenty billions of miles* from the Earth.

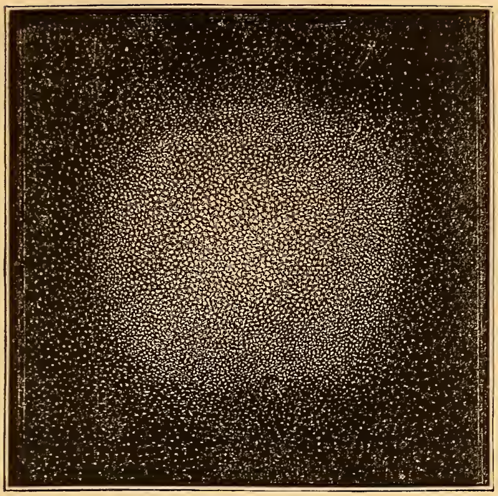
Q. Describe the OTHER STARS in Centaurus.

A. In the horse's leg, five degrees west of α, (Alpha,) is β, (Beta,) a star of the first magnitude; about twenty-five degrees north of β, (Beta,) is δ, (Delta,) in his left shoulder; and eight degrees west of δ, (Delta,) is ι, (Iota,) in his right shoulder; these two stars, with μ, (Mu,) in his breast, form a small triangle. Four small stars constitute his face.

Q. Is there any remarkable TELESCOPIC object in this constellation?

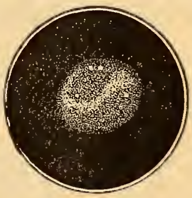
A. About *thirty-six degrees* due south from Spica in Virgo is a small star called ω (Omega) Centauri, which, to the naked eye, appears of the fifth magnitude, and a little hazy. When seen through a good telescope, it proves to be a globular cluster consisting of thousands of stars.

Fig. 166.



The above figure represents this wonderful object, which, Sir John Herschel remarks, is "truly astonishing." There are other nebulæ and some double stars in this constellation. There is a double star in the breast, which appears to be surrounded by a luminous atmosphere. It is a very interesting object, but is only visible through the telescope.

Fig. 167.



Q. Is there any other remarkable object in Centaurus?

A. Near the fore feet of the Centaur is a remarkable nebula, which contains three small stars, one of which appears double, with a high magnifying power. Several minute stars may be detected in it.

Fig. 168.

Q. In what PART of this constellation is the remarkable SPLIT nebula?

A. In the *breast* of the Centaur is a remarkable nebula with two divisions, with a streak of nebulous light between them.

The annexed figure is taken from a drawing by Sir John Herschel.

AVIS SOLITARIUS.

Q. Where is Avis Solitarius to be FOUND?

A. It is immediately *south* of Libra; it is represented by an *owl* standing on Hydra, and its head within the limits of the zodiac.

Q. Are there any CONSPICUOUS stars in this constellation?

A. No; this constellation was formed by Le Monnier in the year 1776, and consists of small stars.

LUPUS.

Q. Where is the constellation LUPUS?

A. It may be seen on the meridian on the 21st of June, at nine o'clock in the evening, *south of Libra and Scorpio.*

Q. How is it REPRESENTED?

A. By a *wolf*, into which Centaur is about to plunge a spear. It contains no conspicuous stars.

CIRCINUS.

Q. What is that small constellation SOUTH of Lupus?

A. *Circinus.* It is situated in the Milky Way, and is composed only of small stars.

CRUX.

Q. There is a small constellation south of Centaurus, directly between the horse's feet: what is its NAME?

A. *Crux*, or the *Cross.* It is formed of *four* principal stars—one of the first magnitude, two of the second, and one of the third.

Q. Where is the principal star SITUATED?

A. In the lower extremity of the cross; it is called α (Alpha) Crucis, and is situated about *two degrees* east of the *equinoctial colure.*

Q. How are the OTHER THREE principal stars situated?

A. One, *six degrees* north of α, (Alpha,) is called γ, (Gamma;) about *four degrees* south-east of γ (Gamma) is β, (Beta;) and five degrees west of β (Beta) is δ, (Delta.)

Q. Are there any TELESCOPIC OBJECTS worthy of note in this constellation?

A. About *five degrees* north of α (Alpha) is $\varkappa$ (Kappa) Crucis; near which is a beautiful *cluster* of stars of different colors and brilliancy.

Q. DESCRIBE this cluster as it appears through the telescope.

A. It occupies an area of only a *forty-eighth* part of a square degree, and yet it contains *one hundred and ten* stars, of the richest colors, giving it the effect, as Sir John Herschel says, of a "rich piece of fancy jewelry."

The central and principal star of this cluster is a deep red; among the larger stars are some green, others blue, and all possessing great brilliancy. This beautiful constellation is invisible to all the inhabitants of the Earth north of 35° north latitude.

MUSCA AUSTRALIS.

Q. Where is Musca Australis SITUATED?

A. Immediately *south* of Crux, and *sixty-seven* degrees south of the equinoctial. It is represented by the figure of a *fly* or *bee*, and contains no very conspicuous stars.

This is a new constellation, introduced by Bayer.

CHAMELEON.

Q. Where is the constellation CHAMELEON?

A. *South* of Musca, and *east* of Pisces Volans. It consists of only small stars.

This constellation is new, and one of the twelve introduced by Bayer, a German astronomer who lived in the seventeenth century.

NORMA.

Q. What CONSTELLATION is that situated east of Lupus, and between Circinus and Scorpio?

A. A new constellation called *Norma*, introduced by Lacaille, a French astronomer who lived in the last century, and spent four years at the Cape of Good Hope, where he surveyed the whole southern hemisphere.

In this constellation there is a singular cluster or knot of telescopic stars, which appears like a picture in the middle, and surrounded by a square frame, which is composed also of minute but bright stars.

ARA.

Q. What constellation is that EAST of Norma?

A. *Ara.* It is one of the old forty-eight constellations, and may be found south of the tail of Scorpio.

Q. Describe the PRINCIPAL stars in Ara?

A. *Thirty degrees* south-east of Antares in the heart of Scorpio, and *twenty-two degrees* north-east of α (*Alpha*) Centauri, is γ, (*Gamma*,) a star of the second magnitude; about one degree north of γ is β, (Beta;) *six* degrees north of β is α, a star of the third magnitude. The other stars in this constellation are of the fourth, fifth, &c. magnitude.

Ara is situated in the Milky Way.

TELESCOPIUM.

Q. What CONSTELLATION is that east of Ara and the tail of Scorpio?

A. *Telescopium.*

This constellation was introduced by Lacaille.

CORONA AUSTRALIS.

Q. What is the NAME of the constellation situated between Telescopium and Sagittarius?

A. *Corona Australis*, one of the old forty-eight asterisms. It contains no stars brighter than of the fifth magnitude.

The telescope reveals some superb *double* stars in this constellation.

PAVO.

Q. How is Pavo SITUATED?

A. Pavo, one of the modern constellations, formed by Halley, is situated *south* of Telescopium, and *south-east* of Ara.

Q. DESCRIBE the stars in Pavo.

A. The principal, α, (*Alpha*,) a star of the second magnitude in the head of Pavo, comes to the meridian about 9 o'clock in the evening, on the 10th of September. About 10° south-east of α is γ, (*Gamma*,) a star of the third magnitude in the breast. This star, as well as β, (*Beta*,) a star 4° to the west of it, are within 1° of the *Antarctic Circle.* A numerous assemblage of small stars constitutes the tail, which is expanded towards the west.

TRIANGULUM AUSTRALIS.

Q. Describe the SITUATION of Triangulum.

A. It is west of Pavo; the *Antarctic Circle* passes through the *middle* of this constellation.

Q. What are its PRINCIPAL stars?

A. At its *eastern* angle is α, (*Alpha*,) a star of the second magnitude; about *six* degrees north-west of α is β, (Beta,) a star of the third magnitude, in the northern angle; and *eight* degrees west of β is γ, (Gamma,) in the third angle of the triangle.

The other stars in this constellation are small.

APUS.

Q. Where is Apus to be FOUND?

A. It is *east* of Musca Australis, and within 13° of the south pole. Apus is a new constellation, introduced by Bayer. It is represented by a bird of paradise flying towards the east. All the stars in this constellation are *very small.*

OCTANS.

Q. What is the NAME of the constellation on which Pavo is represented as standing?

A. *Octans Hadleianus.* This is a new constellation, introduced by Lacaille in honor of Hadley.

Q. Does this constellation contain any BRIGHT stars?

A. There are no stars in this constellation above the *fifth magnitude.*

The south pole of the heavens is in the constellation Octans.

MICROSCOPIUM.

Q. Where is the constellation Miroscopium SITUATED?

A. *South* of Capricornus and *east* of Sagittarius.

Q. Does it contain any conspicuous STARS?

A. It does *not.* It is one of the new constellations formed by Lacaille, and contains only small stars.

GLOBUS ÆTHEREUS.

Q. What is that small new CONSTELLATION east of Miroscopium and south of Capricornus?

A. *Globus Æthereus*, the *Balloon.*

Q. Are there any LARGE stars in this constellation?

A. No; there are *none* above the *fifth* magnitude.

PISCES AUSTRALIS.

Q. Designate the PLACE of this constellation.

A. It lies immediately *south* of Aquarius, and *eight degrees* south of the Tropic of Capricorn.

Q. Does this constellation contain any LARGE stars?

A. Yes; there is one called *Fomalhaut*, of the *first* magnitude, in the eye of the Fish.

Fomalhaut is derived from the Arabic *fom-al-hut*, "the Fish's mouth." It is still represented in the mouth of the Fish on some charts, but is generally drawn to form the eye in new maps.

Q. Describe the OTHER STARS in this constellation.

A. About *six degrees* south-east of Fomalhaut is β, (*Beta,*) a star of the *third magnitude*, in the fin; and five degrees north-east of β is ε, (*Epsilon;*) the three forming a triangle.

The head of the Fish is towards the east, and its tail comes in contact with Globus Æthereus.

Q. When does Fomalhaut come to the MERIDIAN? and in what latitude is it VISIBLE?

A. It comes to the meridian on the *twenty-fifth* of October, at 9 o'clock in the evening, and is visible to all places on the Earth except those situated north of the parallel of *fifty-nine and a half degrees* of north latitude.

APPARATUS SCULPTORIS.

Q. Where is APPARATUS situated?

A. It is *south-east* of Pisces Australis; the *equinoctial colure* passes through the middle of it. It contains no stars above the fifth magnitude.

PHŒNIX.

Q. What CONSTELLATION is that situated south of Apparatus Sculptoris, on the equinoctial colure?

A. *Phœnix.*

Q. DESCRIBE the stars in Phœnix.

A. *Twenty-two* degrees *south-east* of Fomalhaut is α, (Alpha,) in the head; it is a star of the second magnitude. *Ten degrees east* of α is γ, (*Gamma,*) in the eastern wing.

TOUCANA.

Q. There is a constellation immediately south of Phœnix through which the equinoctial colure and Antarctic Circle pass: what is the name of that asterism?

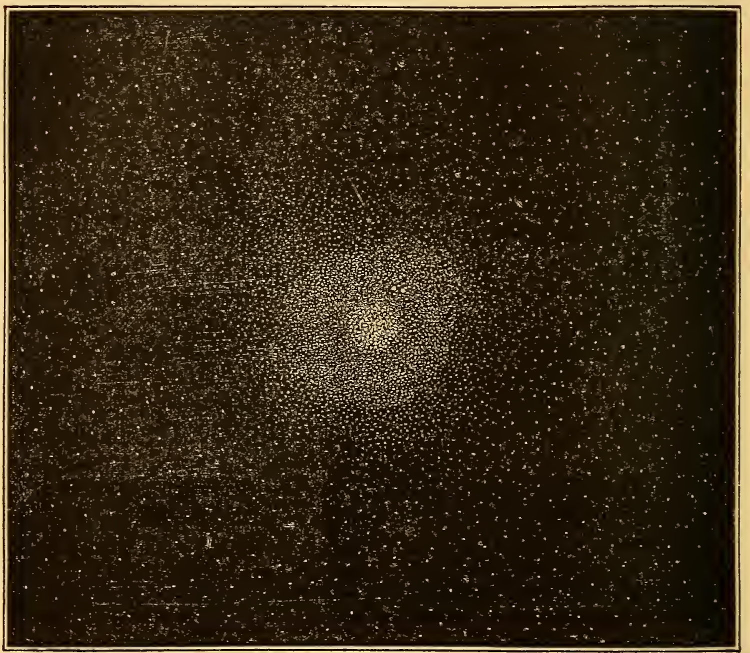
A. *Toucana.* A star marked α, (Alpha,) of the third magnitude, denotes the bill; fifteen degrees south-east of this is β, (*Beta,*)

a star of the third magnitude, in the tip of the wing; η (*Eta*,) is situated about the middle of the body, and about twelve degrees south-east of α, (Alpha.)

Q. Are there any TELESCOPIC OBJECTS in Toucana?

A. There is a star called 47 Toucani.

Fig. 169.



This magnificent cluster is copied from that in the "Observations at the Cape of Good Hope." Sir John Herschel calls it a "*glorious object.*" It is one blaze of light in the centre, where may be seen a double star.

GRUS.

Q. Where is Grus SITUATED?

A. *South* of Pisces Australis, and *west* of Apparatus Sculptoris.

Q. DESCRIBE the stars in Grus.

A. Eighteen degrees south-west of Fomalhaut is α, (Alpha,) in the back; about five degrees south-east of α is β, (Beta;) thirteen degrees north-west of β is γ, (Gamma,) in the head. The other stars in this constellation are small.

INDUS.

Q. What CONSTELLATION is that situated between Grus on the east and Pavo on the west?

A. Indus.

Q. How is it REPRESENTED on the maps and globes?

A. By the figure of an *Indian*, with a spear in one hand and a shield in the other. This is one of the new constellations introduced by Bayer. It consists only of minute stars.

CETUS.

Q. What is the NAME of that large constellation situated south of Aries and Pisces, and east of the equinoctial colure?

A. *Cetus.* It is the *largest* constellation of the firmament.

Q. What star is that in the Whale's NOSE?

A. *Menkar*, or, as it is sometimes written, *Menkab.* It is situated *twenty-two* degrees south-east of Arietis, and is a star of the *second* magnitude.

It is called Menkar from the Arabic *Al-minkhir*, 'the nose or snout."

Q. When does Menkar come to the MERIDIAN?

A. At *nine* o'clock in the evening on the *nineteenth* of *December.*

Q. What very REMARKABLE star is there in Cetus?

A. There is a star in the *neck* of the Whale which is *variable.* Sometimes it is a star of the second magnitude or brightness, when it diminishes in lustre until it becomes invisible; after which it increases again in brilliancy, until it arrives to that of a star of the second magnitude.

Q. What is the NAME of that remarkable star?

A. *Mira.* It is also known as *o* (Omicron) Ceti; sometimes it is called *Mira Ceti;* it is also designated by some as *Collo Ceti*, because it is in the *neck* of the Whale.

Mira, from *mirabilis*, "wonderful." Thus Mira is called the "wonderful star."

Q. What is the PERIOD of Mira? that is, how long does it require to change from its greatest brilliancy to bright again?

A. Once in *three hundred and thirty-one days, fifteen hours, and seven minutes.*

According to Cassini, a French astronomer, its period is 333 days; Ismael Bullialdus estimated its time to be 334 days; while Halley mentions that it passes through all its variations seven times in six years. Sir John Herschel calculated its period to be about twelve times in eleven years, or the more exact time of 331 days, 15 hours, 7 minutes. It remains at its greatest brightness about two weeks, decreases so as to become invisible in about three months, remains invisible about five months, and continues increasing during the remainder of the period, or about 77 days. Hevelius, a celebrated German astronomer, who lived in the seventeenth century, states that he watched it constantly from 1648, and that from the years 1672 to 1676 it did not appear, although it was the particular object of his attention. On the 5th of October, 1839, it was unusually bright.

Q. Who DISCOVERED Mira?

A. It was discovered in 1596 by *David Fabricius*, an astronomer, and disciple of Tycho Brahé.

Q. About TEN degrees to the south west of Mira is a star of the THIRD magnitude: what is its NAME?

A. *Baton Kaitos*, or ζ (Zeta) Ceti.

Fig. 170.

Q. DESCRIBE the other principal stars in Cetus.

A. About *five* degrees west of Menkar, in the nose, is γ, (Gamma,) a star of the *third* magnitude; about five degrees south-west of γ (Gamma) is δ, (Delta;) *thirteen* degrees south of δ (Delta) are four small stars, forming an irregular square: they are ε, (Epsilon,) π, (Pi,) ς, (Sigma,) and ρ, (Rho.) This square lies about *six* or *eight* degrees south-east of Baton Kaitos. About midway between Baton and Fomalhaut, in the Southern Fish, is β, (Beta,) or *Diphda*, in the curl of the tail. In the extremity of the tail is ι, (Iota,) *Deneb Kaitos* or *Shemeli.*

Q. Is there any remarkable TELESCOPIC OBJECT in Cetus?

A. There is a long, narrow *nebula* in the tail of Cetus, about eight degrees south of β, (Beta.) It was discovered by Miss Herschel in 1783, and is described as having a singularly pale, milky tint. The annexed figure is a representation of it.

PSALTERIUM GEORGIANUM.

Q. How is the constellation Psalterium Georgianum REPRESENTED?

A. By a *harp*, which is situated between the paws of the Whale and the feet of Taurus.

Cetus, or the Whale, is represented on the map as a monster with a tail like a fish, but having *paws* somewhat resembling those of a dog.

Q. Does this constellation contain any CONSPICUOUS stars?

A. It does *not.* There is one star in this constellation, called *Reid*, which comes to the meridian with the Pleiades; it is a star of the fifth magnitude.

This is one of the new constellations, and is not acknowledged by all astronomers. It was formed by Maximilian Hell, a Hungarian astronomer, in honor of George II. of England.

ERIDANUS.

Q How is this constellation REPRESENTED on the maps and globes?

A. By a *stream*, which issues from between the paws of Cetus; the principal branch runs eastwardly, then makes a bend towards the west and south-west, as far as Phœnix and Toucana; this is called the *Southern Stream.* The other branch, or the *Northern Stream*, lies between Orion and the paws of Cetus.

Q. Is there any star of the FIRST magnitude in Eridanus?

A. Yes; in the southern extremity of the stream is the beautiful bright star, *Achernar*, which is of the first magnitude or

brilliancy. It is situated *fourteen* degrees south of γ (Gamma) Phœnicis, and forms a right angle with that star and α (Alpha) Toucani, in the bill of Toucana.

Achernar is invisible to all the inhabitants of the Earth situated north of 32° north latitude.

Q. Describe the OTHER STARS in this constellation.

A. About *eighteen* degrees south-west of Rigel, in Orion's foot, is γ (Gamma) Eridani, a star of the second magnitude; it is sometimes called *Zaurak*.

The other stars in this constellation may easily be traced on the map.

SCEPTRUM BRANDENBURGIUM.

Q. Describe the constellation SCEPTRUM BRANDENBURGIUM.

A. It is a small new constellation, situated between *Lepus* and *Eridanus*, and south of *Orion* and *Taurus*. It contains no very conspicuous stars.

This constellation was formed in 1688 by Kirch, a celebrated German astronomer. His wife, Mary Margaret, was his assistant, and the author of several astronomical works.

CELA SCULPTORIA.

Q. Where is Cela Sculptoria SITUATED?

A. It is directly *south* of Sceptrum Brandenburgium, and lies between Columba and Eridanus. It is represented by two graver's tools crossed, one over the other. It contains *no bright stars*.

DORADO.

Q. Where is the constellation DORADO, and how is it REPRESENTED?

A. It is represented as a *sword-fish*, and is situated *south* of Equuleus Pictorius. The solstitial colure and the Antarctic Circle cross each other in the head of the Fish. This point is the pole of the ecliptic.

Q. Where is the PRINCIPAL star of this constellation SITUATED?

A. About *fifteen* degrees *west* of Canopus, in Argo Navis. The other stars in this constellation are small.

Q. Are there any remarkable TELESCOPIC OBJECTS in Dorado?

A. About three degrees from the south pole of the ecliptic is a nebula, one of the most singular objects which the heavens present. It is situated in the thickest of the *Nubecula*, or Magellanic Clouds, and occupies about the *five hundredth part* of the Greater Nubecula.

This was numbered 30 Doradus, by Bode, a German astronomer, who died in the early part of this century.

Fig. 171.

This nebula contains numerous stars when seen through a good telescope. Sir John Herschel has made a catalogue of more than a hundred in this nebula alone. The representation is taken from the drawing in his work, "Observations at the Cape of Good Hope."

FORNAX CHEMICA.

Q. Where is Fornax Chemica to be FOUND on the map or globe?

A. It is situated in the *bend* of the Southern Stream of Eridanus, to the *west* of the river. The principal star, called *a*, (Alpha,) lies about *thirty-five* degrees southwest of Rigel, in Orion's foot. The other stars of this constellation are not conspicuous.

Fig. 172.

Q. What TELESCOPIC OBJECT is there in this constellation?

A. There is a nebula, discovered by Sir John Herschel, which he describes as very bright in the centre, and being elliptical in its form. Three or four small stars appear near it.

The annexed figure is copied from one by Sir John Herschel.

MACHINA ELECTRICA.

Q. By WHOM was this constellation introduced?

A. By *Lacaille.* It is situated immediately south of Cetus, and north of Phœnix, and contains no bright stars.

HOROLOGIUM.

Q. What CONSTELLATION is that situated south-east of Phœnix?

A. *Horologium.* This constellation was also introduced by *Lacaille.* It contains no very bright stars.

SOLARIUM.

Q. Where is Solarium SITUATED?

A. *East* of Horologium, and, like it, contains no remarkable stars.

RETICULUS RHOMBOIDALIS.

Q. DESCRIBE the constellation Reticulus.

A. It is represented by a large net, and is situated between *Dorado* and *Horologium.*

This is a new constellation, formed by Lacaille.

HYDRUS.

Q. How is this constellation REPRESENTED?

A. By a *water-snake*, the head of which is between Toucana and Horologium. It winds round to the west, then to the east, touching Reticulus, and its tail ends at or near the south pole.

The Nubecula Minor, or Lesser Magellanic Cloud, is in the constellation Hydrus.

Q. Where is the PRINCIPAL star in Hydrus?

A. In the *head*, about five degrees south-east of Achernar. There are two other stars of the third magnitude in Hydrus, δ, (Delta,) in the middle of the body, and β, (Beta,) in the tail, about ten degrees from the south pole.

MONS MENSÆ.

Q. What constellation is that SOUTH of Dorado, and BETWEEN Hydrus and Pisces Volans?

A. *Mons Mensæ.* It contains no large stars, but the Great *Magellanic Cloud*, or *Nubecula Major*, is situated in this constellation.

PART IV.

Practical Astronomy.

"Here truths sublime, and sacred science charm,
Creative arts new faculties supply;
Mechanic powers give more than giant's arm;
And piercing optics more than eagle's eye."

Practical Astronomy treats of astronomical instruments, and their application. These instruments are usually placed in a building called an observatory, which is erected in a suitable situation for obtaining an uninterrupted view of the heavens.

CHAPTER I.

General Properties of Light.

Before entering on a description of the astronomical instruments used in an observatory, it will be necessary to have some knowledge of the general properties of light.

Light is supposed to be caused by the undulations or vibrations of an elastic fluid called ether, which pervades all space. These undulations or vibrations, reaching the eye, affect the optic nerve, and produce the sensation which we call light.

The progressive motion of light is generally believed to be *undulatory;* that is, the rays of light traverse the space between the object and the eye in wavelike lines. Although light is supposed to be propagated from the luminous body in wave-movements through space, yet its rays are emitted in *parallel lines*, and from all points in the luminous surface.

Light requires time for its propagation, which has been fully proved by the discovery of the aberration of light, which has been already explained in a former part of this work.

Light is found to be uniform in its motion; rays from the Sun, a planet, or fixed star, move with the same velocity; and as we know these bodies to be at very different distances from us, we conclude that the velocity of light is independent of the particular source from which it emanates, and the distance over which it has travelled before reaching our eye. The rate of motion of light through space is therefore considered as uniform, but its velocity is supposed to undergo a change when it enters such media as the atmospheres of the Earth and other planets. Its mean velocity is estimated at 192,000 miles per second.

The illuminating power of any source of light is found to diminish as its distance from the luminous body increases. A flat surface of a given area freely and perpendicularly exposed to a luminary at different distances, receives a quantity of light inversely as the squares of the distance from the luminary.

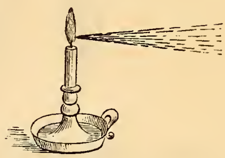
Thus, a person situated at two feet from a candle has only one-fourth part of the light he would have if situated at one foot from it; at the distance of three feet he would have nine times less; and at four feet, sixteen times less light than if he was one foot from the candle.

In order to ascertain the intensity of any given light, an instrument called a *photometer* is used, which, however, does not satisfactorily answer the purpose for which it was intended.

Light is propagated in right lines, each of which is called a *ray;* and each ray is supposed to issue from a luminous point in the illuminating body.

A collection of parallel rays is called a *beam* of light; and a collection of rays diverging from, or converging to a point, is called a *pencil of light*, as is represented in the annexed figure.

Fig. 173.



PENCIL OF LIGHT.

That light is propagated in right lines, may be proved by the fact that we cannot see as well through a crooked tube as through a straight one; and the outline of a shadow corresponds exactly with that of the object as seen from the luminous body.

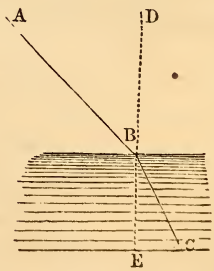
SECTION I.

Refraction of Light.

Refraction is the inflection or bending of the rays of light out of their natural course. They always pursue straight lines, without any deviation, unless they pass obliquely from one medium to another, in which case they leave their original path and assume a new one. This change of direction of the rays of light is called *refraction.* After a ray has been refracted—that is, after it has taken a new direction—it then proceeds in a straight line till it meets with another medium, when it is again bent out of its course.

A ray of light pursues a curved line when it passes obliquely through a medium the density of which changes uniformly. A ray of light from a heavenly body passes through our atmosphere in a curved line, because the different strata of the atmosphere become uniformly more dense as it descends towards the Earth. But if it passes at once into a denser medium, its course is changed at the point of contact, into a path making a greater or less angle with the surface of the denser medium.

Fig. 174.

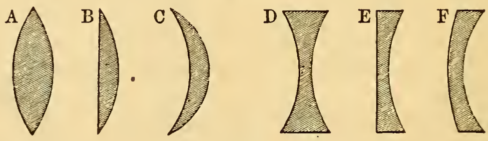


Let A B be a ray of light, and B the point in which it enters from the air into the water. This ray, by the greater density of the water, instead of following its first direction, will be bent at the point B, and follow the line B C, which is called the *refracted* ray.

When light falls perpendicularly on the surface of a transparent medium, it passes through it without being refracted. In the above figure let the line D B represent a ray of light; its course is not cnanged, but it pursues the line D B continued to E. Thus, a ray from a star, or other heavenly body in the zenith, suffers no refraction, but reaches the eye of the observer in a line perpendicular to the plane of his horizon.

A *lens* is a piece of glass, or other transparent substance, having its two surfaces so formed that the rays of light, in passing through it, have their direction changed and made to converge and tend to a point beyond the lens, or to become parallel after converging or diverging; or, lastly, to diverge as if they had proceeded from a point before the lens. Lenses may be divided into convex and concave.

Fig. 175.



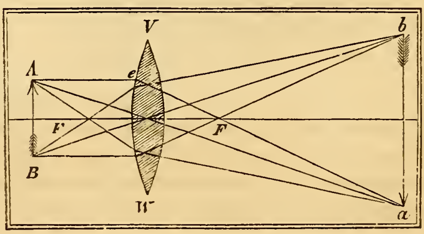
LENSES.

Among convex lenses are the double convex, A, to which the appellation *lens* was originally applied, from its resemblance to a lentil seed (in Latin *lens*,) being bounded by two convex spherical surfaces, whose centres are on opposite sides of the lens. B represents a *plano-convex* lens, one side of which is bounded by a plane or flat surface, the other by a convex surface. C represents the *meniscus* lens, which is concave on one surface and convex on the other, the concave surface being part of the arc of a larger circle than the convex surface, the two surfaces must meet when produced. D is a *double-concave* lens, or concave on both sides. E represents the *plano-concave* lens, which is plane on one side and concave on the other. F is a *convexo-concave* lens, bounded by a convex surface on one side and a concave on the other; but as the inner or concave surface is a portion of an arc of a smaller circle than that of the outer or convex surface, the two surfaces when produced could not meet.

The *axis* of a lens is a straight line drawn through the centre of its spherical surface.

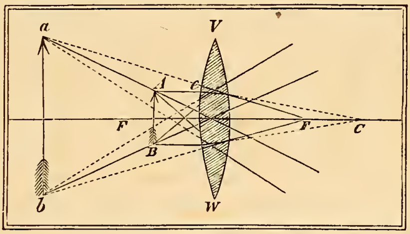
The images formed by lenses will be best understood by reference to the following figure:

Fig. 176.



A B is an object on one side of a double-convex lens, W V, but farther removed from it than the focal point F. The rays which proceed from A are united to a point at *a*, by passing through the middle of the lens, *a* being an image of A. In the same manner the rays from B pass through the centre and form an image at *b*; thus, the object A B is represented inverted at *a b*. The size of the image is regulated by the distance of the external object from the lens. If the object be removed more than twice the distance of the focus, the image will be nearer, and we obtain a diminished image; if the object be brought nearer to the lens, the image recedes, and is enlarged. In lenses of short focus the images lie nearer the glass than in those of greater focal distance.

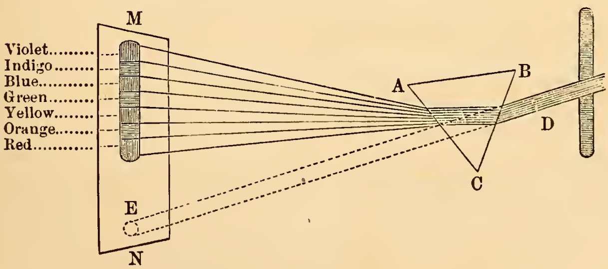
Fig. 177.



Let A B(*fig.* 177) be any object nearer the lens than its focal distance; then the rays from it *diverge* on leaving the lens W V, and the eye placed at C, which is just at the focal point, sees an image at *a b*. The object and the image lie within the angle *a o b*; but the object being nearest the glass, we see the image magnified. In microscopes, the images formed are of this kind.

A ray of solar light is found to be composed of different colors, which may be separated from each other by means of a prism. If a beam of sunlight be admitted into a dark room through a small aperture in a close shutter, and suffered to pass unobstructed, it would fall on a flat or plane surface—a sheet of paper, for instance—and form a circular disc of white light.

Fig. 178.



This disc is represented at E, and is formed by the ray D, which, before the prism A B C was placed in its path, followed the straight line D E. By placing the prism between the shutter and the screen M N, so that the ray may enter and quit it at equal angles, it will be refracted in such a manner as to form on the

screen M N an oblong image, called the *solar spectrum*, which will be divided horizontally into seven colored spaces or bands of unequal extent, succeeding each other in the order represented—*red*, *orange*, *yellow*, *green*, *blue*, *indigo*, and *violet.* The *red* ray is the least, and the violet the most, refrangible of the spectrum.

SECTION II.

Reflection of Light.

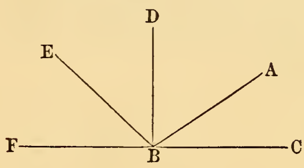
The reflection of the rays of light is that property by which, after approaching the surfaces of bodies, they are *thrown back* or repelled. By the reflection of light we are able to discern all the objects around us, terrestrial as well as celestial.

Rays of light which fall on rough or uneven surfaces are reflected in all directions, and very irregularly; whereas, from smooth and polished surfaces, they are reflected with regularity. Highly polished surfaces are called *mirrors* or *specula*

Mirrors may be classed into three kinds—*plane*, *concave*, and *convex* mirrors, according as they are bounded by plane, concave, or convex surfaces. The most familiar illustration of a plane mirror is the common *looking-glass.*

When a ray of light falls upon a plane mirror, rather more than the half of it is reflected or thrown back in a direction similar to that in which it falls. Thus, if a ray fall *perpedicularly* on a plane mirror or looking-glass, it will be reflected perpendicularly; but if it approach the glass in an oblique direction, it will be reflected in a line having the same obliquity as that by which it reached the glass. From these facts the following law has been deduced, namely: *the angle of reflection is, in all cases, exactly equal to the angle of incidence.* This law holds good in regard to concave or convex mirrors, as well as to the plane mirror or common looking-glass.

Fig. 179.



Let F C (*fig.* 179) be a plane mirror, and A B the line of incidence, or, as it is sometimes called, the incident ray; then E B would be the line of reflection, for as the angle of the line of incidence is always equal to the angle of reflection, the angle A B D must be equal to the angle D B E, which is the angle of reflection.

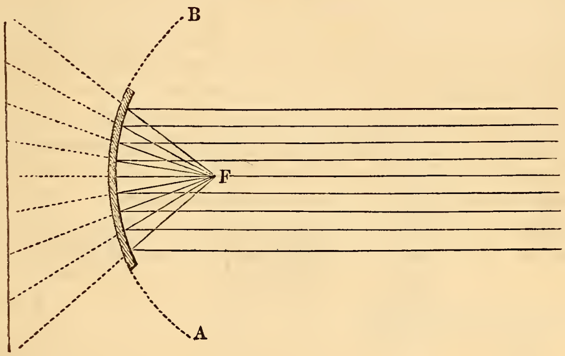
In rolling a marble obliquely against a wall, the path of the marble from the hand to the wall would represent the line, or ray of incidence, the wall would take the place of the mirror, and the path of the marble, as it would leave the point of the wall which it struck, would represent the line of reflection; for the path of the marble towards the wall would have the same angle with the wall which its path on receding from the wall would have with it.

Concave mirrors or speculas are of the greatest importance in constructing refracting telescopes. They cause parallel rays to converge, increase the convergence of converging rays, and diminish the divergence of diverging rays.

In the following figure let A B represent a concave mirror, which, it will be understood, is the *arc of a circle.* The parallel rays fall upon it, and are reflected back, and converge at a point F, at a distance from the mirror equal to *half the radius of which the mirror is an arc.* The point of convergence F is called the

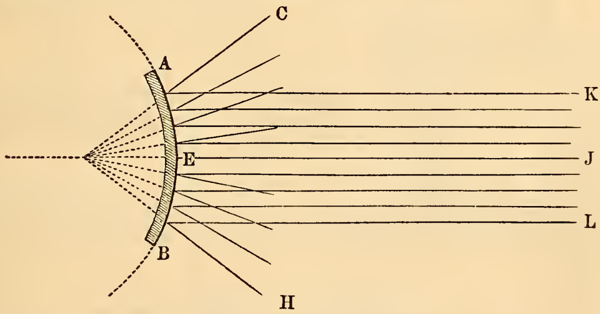
focal point, or focus of the mirror. And as the rays of light are always parallel to each other, if the mirror be exposed to the direct rays of the Sun, they would fall on the mirror A B, and be reflected back to the *focal point* F, where, if the quantity of rays collected by the mirror are sufficient, they would set fire to a combustible material.

Fig. 180.



Convex mirrors always cause the image to appear *behind* the reflecting surface. The image is always *smaller* than the object; the image of a straight object always appears curved in a convex mirror, because the rays of light coming from the object are not all of the *same length* when they reach the mirror, on account of its convex surface.

Fig. 181.



In the above figure, A E B represents the convex surface of the mirror, and K A, J E, L B parallel rays falling upon it. These rays, when they strike the mirror, are made to diverge in the direction A G, B H, &c. and both the parallel and divergent rays are represented as they appear in a dark chamber, when a convex mirror is presented to the solar rays.

Fig. 182.

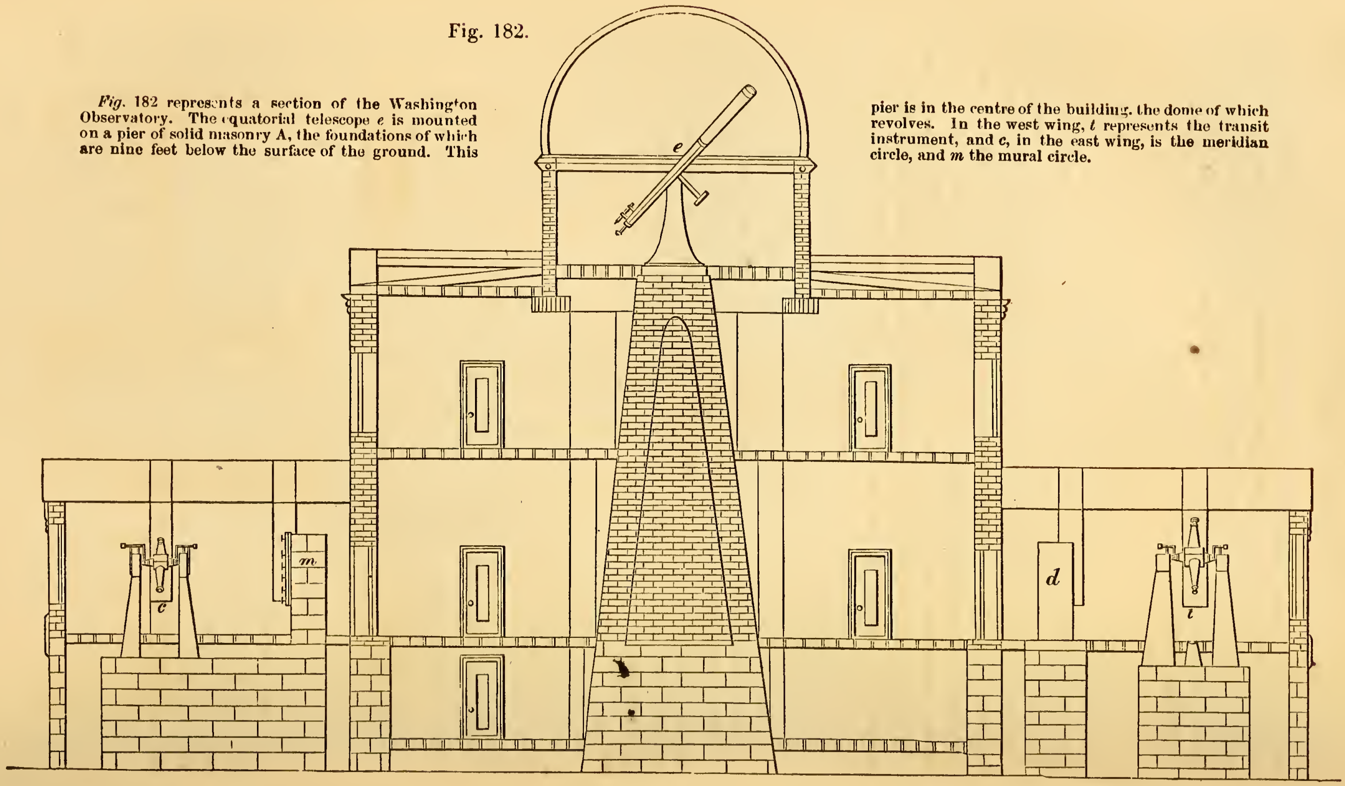


Fig. 182 represents a section of the Washington Observatory. The equatorial telescope *e* is mounted on a pier of solid masonry A, the foundations of which are nine feet below the surface of the ground. This pier is in the centre of the building, the dome of which revolves. In the west wing, *t* represents the transit instrument, and *c*, in the east wing, is the meridian circle, and *m* the mural circle.

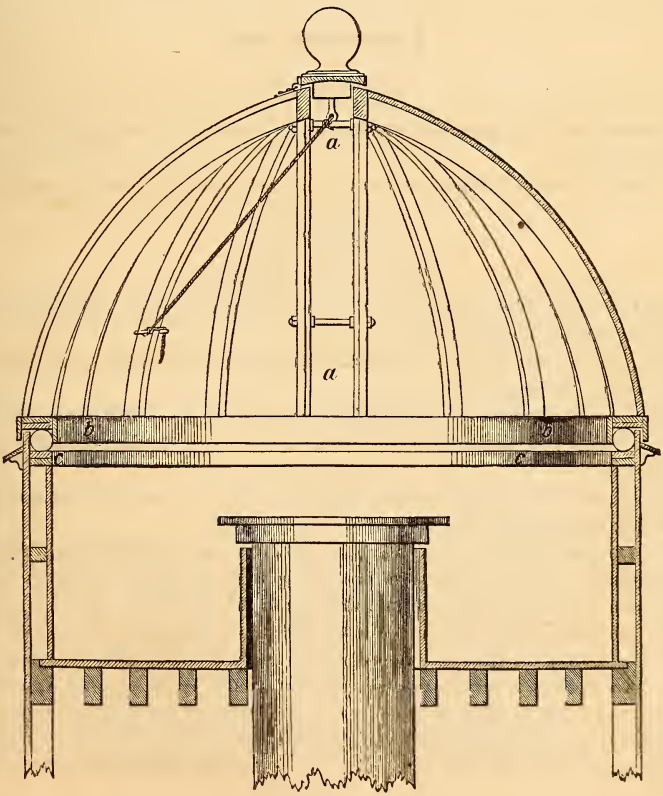
CHAPTER II.

The Observatory.

The best site for an observatory is a situation a little elevated above surrounding objects, at a distance from manufactories or other buildings which emit much smoke; it should also be at a distance from swampy ground, or valleys which are liable to be covered with fogs or exhalations. The ground should be gravel or other solid stratum, and not too close to a public road. It is generally considered important to have access to some distant field, where a pillar may be erected, on which to fix a meridian mark. This consists of some mark fixed on an immovable block of stone, situated exactly north of the observatory; or in other words, a line drawn due north from the axis of a fixed telescope shall intersect the meridian mark. Sometimes there is also a meridian mark to the south of the observatory.

Observatories are usually constructed with a revolving dome, and a door in it opening so as to admit a view from the zenith to the horizon.

Fig. 183.



The northern and southern horizon of the observatory should be unobstructed by trees or buildings; and, if possible, the whole extent of the heavens should be visible.

Fig. 183 represents a section of the rotary dome of an observatory. The two oblong doors *a a* are each nearly a foot wide, opening outward. These doors meet at the apex of the dome, and when closed, the one which shuts last overlaps the other, thereby excluding the rain and snow. The circular broad rim *b b*, which in the figure appears like a straight line, forms the base of the dome; *c c* is a similar ring, forming the wall-plate on which the dome rests and revolves. A circular bed, formed partly by the dome and partly by the cylindrical framework, receives a set of small brass wheels, or cast-iron balls, of exactly equal diameters. On these the whole dome revolves, and may, by means of a crank, be turned to suit the wishes of the observer. The dome is usually furnished with an equatorial telescope. The above figure of a revolving dome is copied from Pearson's Practical Astronomy, a work which stands pre-eminent in that branch of science.

CHAPTER III.

Telescopes.

A TELESCOPE is an optical instrument, which serves for discovering and viewing distant objects.

Telescopes may be divided into two classes—refracting and reflecting telescopes.

SECTION I.

Refracting Telescopes.

The refracting telescope consists of lenses, through which the objects are seen by rays refracted through them to the eye.

The lens or glass turned towards the object is called the *object-glass*, and that next the eye, the *eye-glass*.

Refracting telescopes are usually fixed or mounted on a small brass pillar or tube, to which is attached three movable feet, which fold up when the telescope is not in use.

Telescopes in observatories are usually firmly fixed on a pier of solid masonry, extending several feet below the surface of the ground.

The aperture of a telescope is the opening of the tube or cylinder in which the object-glass is inserted. The rays proceeding from the object are united by the object-glass to form an image within the tube of the telescope. The distance between the point where this image is formed and the object-glass, is called the focal length of the telescope. In order to magnify the image and render its details more distinct, a microscope, composed of two or more lenses, is applied at the eye end: this is called an eye-piece, (one or more of which every telescope is provided with,) having different magnifying powers. A tube, worked by a milled head, connected with a rack and pinion, is made to slide in the main tube. This

sliding tube receives the eye-piece or microscope, the focus of which may be adjusted to suit the observer by means of the milled head.

Eye-pieces are either positive or negative. The positive eye-piece consists of two plano-convex lenses, placed at a distance from each other less than the focal distance of the lens next the eye, with their plane side outwards, and their curved surfaces towards each other. This kind of eye-piece is used for telescopes with micrometers, and for transit instruments with spider lines in the focus of the object-glass.

The negative eye-piece consists of two plano-convex lenses, having their curved faces in the same direction—that is, towards the object-glass—and placed at a distance from each other nearly equal to half the sum of their focal lengths.

There is another species sometimes used, called the diagonal eye-piece. This consists of a rectangular glass prism, or a flat piece of polished metal, inserted between the two lenses of the eye-piece. The glass is preferable to the metal, because less light is lost or absorbed in the reflection. The piece of metal is placed at an angle of 45° to the axis of the tube; and as the ray of incidence is always equal to the angle of reflection, the ray is reflected into the axis of the eye-piece, which is situated perpendicular to the axis of the telescope, thereby admitting the eye of the observer to be applied to the *side* instead of the end of the telescope.

From what has been said, the depression of the eye end of the telescope cannot incommode the observer, because his observations will be made at the side of the tube. But when very minute double stars are to be examined, the ordinary eye-piece is preferable, as less loss of light is sustained.

SECTION II.

Achromatic Telescope.

In a darkened room, a ray of light received on a screen through a small aperture in a shutter, appears like a round white spot; but when suffered to fall on a prism it is separated into a band of prismatic colors, the breadth of which is equal to the white spot, but considerably extended in length. This is called the *dispersion* of the rays. Different substances have different powers of dispersion; for instance, two prisms of equal size, but constituted of different substances, will form spectra of different lengths.

If a ray of white light fall at a certain angle on a prism of flint glass, and another ray fall on a prism of crown glass at the same angle, the spectrum formed by the flint glass will be found to be much greater than that produced by the crown glass. As the quantity of dispersion depends upon the refracting angle of the prism, the angles of the two prisms may be made such that when the prisms are placed close together, with their edges opposed to each other, the one will counteract the action of the other, and will refract the colored rays equally, but in contrary directions, so that an exact compensation will be effected, and the light will be refracted without color.

Newton made many experiments on the passage of a ray of light through different media, but failed to discover that refraction may be produced without color.

It was found that an object-glass composed of a single lens, instead of causing the rays to converge to one point, disperses them, forming a confused and colored image of the object; but by constructing it of two lenses in contact with each other, and composed of different substances of certain forms and proportions, a perfectly well-defined and colorless image is produced. The substances commonly used for achromatic telescopes are one lens of flint and another of crown glass.

Fig. 184.

The object-glass of an achromatic telescope consists of a convex lens A B (*fig.* 184) of crown glass, placed at the extremity of the tube towards the object, and another concavo-convex lens C D of flint glass, placed towards the eye. As the focal length of a lens is the distance of its centre from the point in which the rays converge, then the lenses A B and C D should be so constructed that their focal lengths shall be in the same proportion as their dispersive powers; in which case they will refract rays of light without color.

The principle of the achromatic telescope was discovered by Mr. Hall, of Warwickshire, England, in 1733; and in 1748, Mr. Dollond, formerly a weaver in London, brought this discovery to perfection.

SECTION III.

Equatorial Telescope.

The equatorial telescope has two axes of motion at right angles to each other When the instrument is properly adjusted, one axis is parallel to the axis of the earth, and is called the polar axis; the other axis is parallel to the plane of the equator, and is called the declination axis. Each of these axes has a graduated circle attached to it, at right angles with its length. The motion required for an equatorially mounted telescope, is that parallel to the plane of the equator; which, being uniform, is produced by means of an attachment of clock-work. This kind of instrument has one advantage over all others—namely, the object is retained in the centre of the field of view for hours, without any effort on the part of the observer.

SECTION IV.

Transit Instrument.

The transit instrument is a telescope fixed at right angles to a horizontal axis, this axis being so supported that the line of collimation may move in the plane of the meridian. The axis, to the middle of which the telescope is fixed, should gradually taper towards its ends, forming cones well-turned and smooth, the bases of which are attached to the telescope.

Transit instruments may be divided into two classes—*portable* and *fixed.* The portable transit, when placed exactly in the meridian and properly adjusted, may be used as a stationary instrument in an observatory, provided the dimensions of

the framework be such as to admit of a telescope of sufficient size. Telescopes having tubes more than $3\frac{1}{2}$ feet focal length, are most advantageously placed on pillars of masonry, having a firm basis below the surface of the ground.

The plate facing page 260 represents the transit instrument in the west wing of the National Observatory at Washington. In this room there is an opening 20 inches wide, and extending entirely across the roof from north to south, and down the wall to within $4\frac{1}{2}$ feet of the floor on each side.

The telescope T attached to this instrument is 7 feet in length, with an aperture of 5 inches. The instrument is mounted on two granite piers P P, 7 feet in height from the floor, and having a base of $2\frac{1}{2}$ feet one way by nearly 2 feet the other way; *a a* are two lamps for illumination, *b b* the supporting arms, and *w w* are compensations which preserve the lamps in an upright position; *p p* screens to soften the light; *e* is a level attached near the object-end of the telescope. A is the handle of the screw which fastens the clamp end to the axis of the instrument; a slow motion in altitude is given to the telescope by means of the handles B B. S S are brass pillars placed on the top of the granite piers P P; and on the top of each of the brass pillars is a lever, to the end of which is attached a weight W, which may be made to support part of the weight of the instrument by sliding it along the lever. At one end of each lever is attached a hook X, which supports two friction rollers under the ends of the axis; *t t* are the trunnions, and *f f* the finding circles.

Transit instruments are used to determine the time of the transit of a heavenly body across the meridian, by which its right ascension can be accurately determined.

SECTION V.

Reflecting Telescope.

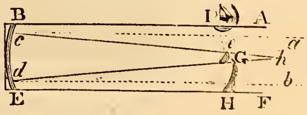
Reflecting telescopes are those which represent the images of distant objects by reflection, chiefly from concave mirrors.

By means of a concave mirror or *speculum*, an image of the object is formed, which is magnified by a lens.

There are four kinds of reflecting telescopes—the *Newtonian*, *Cassegrainian*, *Gregorian*, and *Herschelian*, so called from their respective inventors.

The Newtonian reflector consists of a tube open at one end, in which the rays of light enter parallel to each other and to the sides of the tube. These rays fall on a concave mirror placed at the other extremity of the tube.

Fig. 185.



Let A B E F (*fig.* 185) be the tube of the telescope, the end A F being turned so as to receive the light from the body to be viewed, from which the parallel rays *a b* enter the tube and fall on the concave mirror B E, which reflects them in converging lines towards their focus *h*. But between the focus and the large mirror B E, the plane or flat mirror G is fixed at an angle of 45°, or at right angles to the axis of the tube. This small mirror is supported by an arm H, against which it rests, and being at right angles to the tube, receives the converging rays before they reach the focus *h*, and reflect them to I in the side of

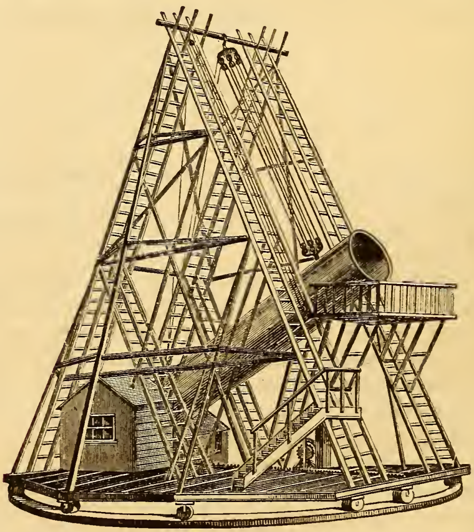
the tube where an eye-piece is placed, which serves to view the image formed at the focus *e*.

The *Cassegrainian* telescope consists of a cylindrical tube, the open end of which is directed towards the object. At the opposite end is inserted a concave speculum or mirror, with an *aperture* in the middle of it. Attached to the large tube is a small tube about the size of this aperture, at the extremity of which the eye is placed, thus enabling the observer to look through the hole in the mirror at a small convex mirror situated near the focus of the large mirror. At the end of the small tube the eye-piece is placed, which magnifies the image reflected into its focus by the small mirror. This kind of telescope is rarely used.

The *Gregorian* reflector is similar to the Cassegrainian, except that the small speculum is concave instead of convex

The kind of reflector most commonly used is the *Herschelian.* This consists of a tube, at the end of which is placed a concave mirror or speculum, a little inclined, so that the rays of light may be thrown a little to the side of the other end, which remains open, and is turned towards the object to be viewed. The observer sits with his back to the heavens, and looks into an eye-piece on that side of the tube towards which the rays from the large speculum throw the reflected image. The eye-piece magnifies the image thus reflected.

Fig. 186.



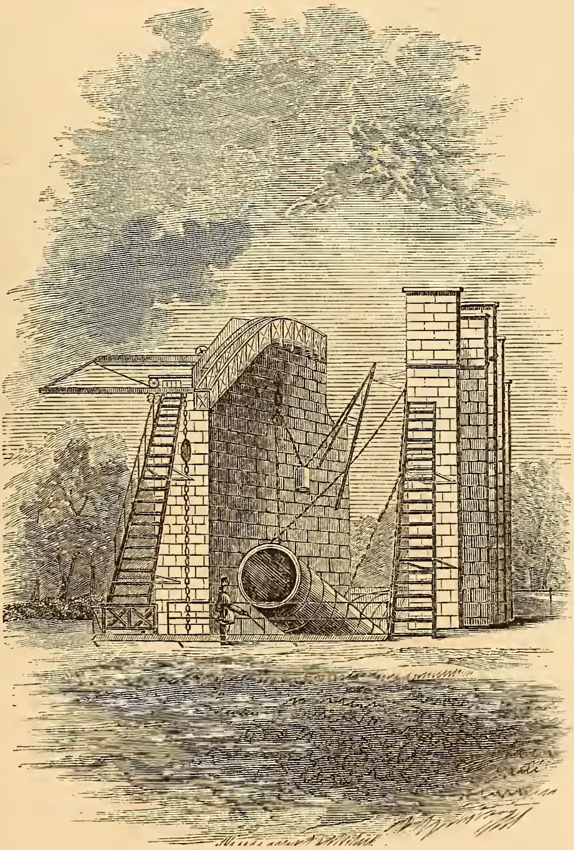
HERSCHEL'S FORTY-FEET REFLECTOR.

The above figure represents the forty-feet telescope constructed by Sir William Herschel. The speculum, composed of metal and highly polished, was 48 inches in diameter, or just 4 feet, and weighed more than 2000 pounds. The tube was made of sheet iron; and the observer, mounted on the staging represented in the drawing, looked down the tube, which could be directed to any part of the heavens

by means of ropes and pulleys, and rollers on which the whole apparatus stands. This telescope is now not fit for use, having been injured on account of exposure to the weather.

The Earl of Rosse has constructed a gigantic reflecting telescope, the tube of which is 6 feet in diameter, its focal length 54 feet, and has a speculum weighing *four tons*. Its superiority consists in the great quantity of light which it reflects, and the brilliancy with which it exhibits objects. It has a reflecting surface of 4071 square inches, while Sir William Herschel's great telescope had only 1811 square inches on the polished surface of its speculum. The cost of this instrument was about sixty thousand dollars.

Fig. 187.



The above figure represents the gigantic telescope of Lord Rosse, with its attachment to the heavy mason-work by means of chains and pulleys. The walls on each side are 24 feet apart, 72 feet long, 48 high on the outer side, and 56 on the inner side. The tube is 56 feet long and 1 inch thick, made of deal and hooped with iron.

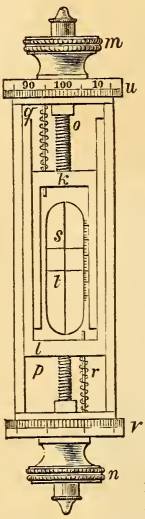
CHAPTER IV.

Micrometer.

The micrometer is an instrument attached to a telescope for the purpose of measuring distances in the field of view. It consists of movable threads or wires, situated exactly in the plane of the focus of the telescope, having a delicately graduated scale outside of the tube of the telescope, whereby we are enabled accurately to measure the dimensions and relative angular distances of the images of the planets or stars.

There are various kinds of micrometers, but that in most general use is the wire or spider-line micrometer, also called the filar micrometer.

Fig. 188.



The annexed figure, copied from the Rev. Dr. Pearson's great work on Practical Astronomy, represents Troughton's spider-line micrometer. This consists of an oblong brass box with a lid, which in the figure is represented as displaced, the interior arrangement being exposed to view.

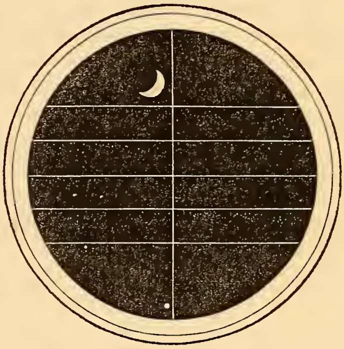
In the annexed drawing, the internal forks *k* and *l* are so nicely fitted into each other, and into the parallel sides of the oblong box, that when they are displaced by their respective screws *o* and *p*, which are turned by the milled nuts *m* and *n*, there is not the least lateral shake; and as the pins *q* and *r*, that pass into suitable holes in the metallic ends of the said forks, have each a spiral spring surrounding them, which press the forks back in a direction opposite to the action of their screws, there is no sensible loss of motion whichever way the screws may respectively turn, which is an important condition in any construction where the measure depends on a screw. There are two spider's lines laid across the forks respectively, one attached to the prongs of the inner fork *k*, and the other to the prongs of the outer fork *l*; and the scratches in which the lines are embedded at the same time insure the parallelism of the two lines, and prevent their touching as they pass over one another, or lie in apparent contact.

When these lines are well placed at the point of their apparent contact, they appear as one line. The long line running at right angles to the small ones may be a wire, as its only use is to place the micrometer in a direction that shall take in both the objects viewed, between which the distance is required to be measured, and to compare the position of that line with a true horizontal or vertical line, as the case may be; and it is convenient to have this line well marked in the field of view.

Notches answering to the size of the threads of the screw, which are divided into fives and tens, are made on one side of the field of view, thus—every tenth notch has a long notch, and between them every five has a rather shorter notch than every tenth, yet longer than the others in the scale. These notches are numbered from the point in the centre called zero, both ways towards the end of the box. The two spider lines may be made to pass one under the other, by means of the

screws, so that they will coincide at the centre or zero. If the angular distance to be measured be considerable, as, for instance, the discs of the Sun or Moon, one of the lines may be drawn fifteen or twenty notches to the left of zero, and then the line moving to the right will complete the measure, when the sum of the two quantities will give the whole number of revolutions and parts indicated. When the angular distance to be measured is small, it will only be necessary to move one of the spider lines, the other being stationary at zero.*

Fig. 189.



In order to render the spider lines in a micrometer visible at night, they are illuminated by means of a small lamp attached to the side of the telescope; thus, the eye of the observer is not exposed to the rays of the lamp, while the spider lines are rendered quite distinct. When the telescope is directed towards the south, the celestial objects enter the field of view from the west side, moving parallel to the horizontal wire. In the annexed figure, copied from that excellent work, Smith's Cycle, the planet Venus, in the form of a crescent, has just entered the field of view, and a star to the left is going off.

CHAPTER V.

Instrumental Adjustments.

SECTION I.

The Vernier.

A VERNIER is a scale or division adapted for the graduation of mathematical instruments, so called from its inventor, Peter Vernier, a gentleman of Franche Comté, who communicated this discovery in the year 1631.

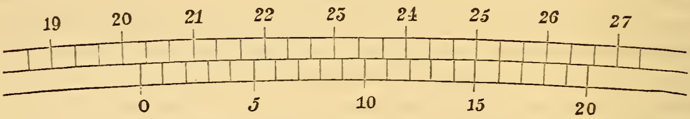
The graduated arc of any instrument is called the limb. To divide or graduate the limb of an instrument, requires great accuracy and the most careful workmanship. It is therefore desirable to make as few divisions as possible, as the smaller subdivisions are liable to be attended with inaccuracy.

The principle on which a vernier is made, is to place a small arc, having the same radius as the instrument, so as to slide in coincidence with it; the small arc to be divided so that it shall contain, in the same length as the outer arc, one more division. Thus, if a certain space of the outer arc contain 19 equal divisions, the same space of the vernier shall contain 20 equal divisions; therefore, it will be evident that each division on the vernier will be one-twentieth part less than a

* See Rev. Dr. Pearson's Practical Astronomy, vol. ii. page 99.

division on the instrument, or that one degree of the instrument is equal to nineteen-twentieths of a division of the vernier.

Fig. 190.



The application of the principle will perhaps be more clearly understood on reference to the above figure, where each degree is seen divided into three parts, and where twenty divisions on the edge of the vernier or inner arc are commensurate with nineteen on the limb or outer arc: the coincidence takes place at 15′ on the vernier with 25° on the limb; and as the zero or stroke 0 on the vernier points to three-fourths of the first division of the twenty-first degree, the reading is 20° 15′; but if this first stroke had fallen in the second space of the same degree, the corresponding reading must have been increased by 20′, so that the angle measured would have been 20° 35′.

SECTION II.

The Level.

In order to render the axis of a transit instrument perfectly horizontal, an instrument called a *spirit-level* is used. It consists of a glass tube ground so accurately within, that the upper side shall be, with regard to its length, very slightly convex upwards. This tube is nearly filled with alcohol or sulphuric ether, and hermetically sealed, so as to include a bubble of air. When this instrument is placed nearly level, the bubble of air contained within the tube will occupy the most elevated portion of the curve.

The levels used for astronomical purposes may be divided into two classes—the *riding* and the *hanging* levels.

The riding level consists of a tube nearly filled with alcohol or ether, and fastened to a flat piece of brass or bar of metal. When the level is to be used, it is placed on the part of the instrument intended to be rendered horizontal, and if the small air bubble stands midway between the ends of the tube, the instrument requires no adjusting; but if the bubble be more to the right than to the left of the centre of the tube, the right side of the instrument requires to be lowered, and *vice versâ*, because the bubble always stands in the highest point of the tube. There is a graduated scale attached to the level, so accurately divided as sometimes to indicate even a second of angular deviation from a true horizontal position.

The hanging level is sometimes attached to two arms, which are suspended from each end of the axis of the transit instrument. The situation of the bubble indicates the horizontality of the instrument, as described above, only the arms by which it is suspended may be unequal; this may be tested by reversing it, and placing what was the right-hand arm on the left. If the bubble still stands in the same position with regard to the observer after the change has been made, the arms are of equal lengths, and the fault lies in the axis of the telescope.

SECTION III.

The Plumb-Line.

The plumb-line, though now but little used, was formerly employed for the same purpose as the spirit-level—namely, for the horizontal and perpendicular adjustment of instruments.

The plumb-line takes its name from the *leaden* weight which was formerly appended to a fine thread of silk, and suspended freely from a fixed pin. As the direction of the string would naturally incline to the centre of the earth, its position was necessarily a vertical one.

A fine thread of silver wire has since been substituted for the silken thread, as being less liable to vibrate; and at the extremity of the wire a small brass bucket, nearly filled with shot, is appended, in the sides of which are some small holes. This bucket is suffered to hang in water to overcome any vibrations.

The use of the plumb-line, though now nearly obsolete, was probably coeval with the construction of the first graduated instruments, to which it has been since used as an index.

By means of the plumb-line applied to Dr. Bradley's zenith sector, the discovery of both the aberration of light and of the nutation of the Earth's axis were made, which data now supply corrections for reducing the apparent to the mean places of the heavenly bodies.

The position of the plumb-line was referred to a very fine point made on the surface of a divided arc at zero, when the point of suspension was on or above the centre of the graduated limb. The permanency of the adjustments made by means of the plumb-line were not very reliable; but these inconveniences were at length removed by the ingenuity of Ramsden, who substituted the *image* of a point for the point itself, which was made to fall exactly at the place of the plumb-line. This was effected by means of an optical contrivance grounded on the principle of the compound microscope, which contrivance has been called Ramsden's *ghost.*

SECTION IV.

Artificial Horizon.

That great circle of the celestial sphere which divides the upper from the lower hemisphere, called the horizon, is of no use to the practical astronomer, owing to the various inequalities of the Earth's surface. It is only in nautical observations made by reflecting instruments, where an allowance is made for the curvature of the surface of the ocean, that the natural horizon can be available. A reflecting plane, situated at right angles to a perpendicular line, may be substituted for the natural horizon, and is therefore called an *artificial* horizon. It is a well-known optical fact, that when a ray of light comes from a luminous body and falls obliquely on a reflecting plane surface, the angle of incidence on that plane, as it has reference either to the plane itself or to a line perpendicular to it, is always equal to the angle caused by reflection; consequently, when a heavenly body is seen reflected from a perfectly horizontal plane, its apparent situation is just as much below the rational horizon as its real situation, when viewed by direct vision, is

above it. Hence, all the heavenly bodies seen by reflection, give *double* the apparent altitude.

Various fluids have been proposed as substitutes for artificial surfaces, of which water, oil, and mercury, well purified, have been found the most useful on trial. These fluids are generally contained in a shallow dish or vessel, which is sometimes covered with a roof to pitch both ways, like the roof of a house; the sides or top of the roof are of glass, to protect the surface from agitation by the wind. The incident ray passes through one glass or side of the roof, and after being reflected from the surface of the liquid, it passes out of the other side of the roof.

SECTION V.

The Collimator.

This instrument, invented by Captain Kater, enables the observer to determine at pleasure the place of the horizontal or zenith point on a vertical circle, without the assistance of the plumb-line, the spirit-level, or any reflecting surface, and that, too, at any time or moment of time.

The principle of the collimator was first employed in 1785, by David Rittenhouse, a celebrated American astronomer and mathematician. He made use of it for the purpose of fixing a definite direction in space, by the emergence of parallel rays from a material object placed in the focus of a fixed lens. There are two kinds of collimators, the *horizontal* and *vertical.*

The horizontal collimator is a telescope of small dimensions, firmly attached to a cast-iron plate floating on mercury, and having a cross-wire in its focus. A telescope thus arranged, when placed on the surface of a basin of mercury, will always assume a horizontal position. By illuminating the cross-wires by means of a lamp, the rays from them will issue parallel, and may therefore be brought to a focus by the object-glass of any other telescope, in which they will form the image of any celestial object in their direction. Thus, the image may be viewed as an infinitely distant star, by an instrument attached to any mural or vertical circle. Since the axis of a floating telescope always preserves the same inclination to the horizon, a reversed observation on opposite sides of the fixed circle, fixes the zenith point of that circle.

The *vertical* collimator consists of a vessel of mercury, towards which the object-glass of a telescope, attached to a circle or a transit instrument, may be directed, so that the cross-wires in its focus may be reflected in the mercury. The wires of the instrument are illuminated by a lamp placed laterally, so that the rays from the lamp may be conducted to the wires without entering the eye of the observer; the telescope is then directed to the surface of mercury. The rays issue from the wires in parallel lines, and are reflected back to the object-glass, which is enabled to collect them again in its focus. By this means a reflected image of the cross-wires is formed, which, when by the motion of the telescope is brought to coincidence with the wires, as seen in the eye-piece of the instrument, indicates the vertical position of the tube of the telescope with great accuracy.

SECTION VI.

The Transit Clock.

One of the chief requisites for an astronomical clock is an invariable pendulum, for on the regularity of its vibrations the indication of time entirely depends. As no single substance has ever yet been discovered, of which a pendulum may be made which is not liable to expand and contract by changes in the temperature, several materials have been successfully used creating an *opposition* of *expansion*, being such an arrangement of the materials used, that while some of them increase the distance of the centre of oscillation from the point of suspension, others shorten the said distance in the same proportion.

As the astronomical clock indicates 0*h.* 0*m.* 0*s.* when the vernal equinox is on the meridian, if the clock shows the time to be 3*h.* 10*m.*, it signifies that it is 3*h.* 10*m.* since the first point of Aries was on the meridian, and does not specify the hour of the day corresponding to the time since the Sun passed the meridian. Astronomical clocks generally indicate sidereal time; that is, the time which elapses between two transits of a star over the meridian of any place.

The most approved clock is that called the *electric* clock. This instrument, which is known by the name of the *electro-chronograph*, is a combination of the magnetic clock, Morse's telegraphic register, a break-circuit key, or instrument for breaking the magnetic circuit. The magnetic clock was invented by Mr. Wheatstone, in 1841. An invention of a similar character was also made by Mr. Bond, of the Cambridge (Massachusetts) Observatory. The object of this instrument is for the determination of the exact period of a transit or other astronomical observation, by which longitude may be ascertained to the hundredth or even thousandth part of a second. The difference of longitude between any two places, is determined by observing the period of the occurrence of certain celestial phenomena, such as eclipses, transits, occultations, &c. In order to insure perfect accuracy, the utmost exactitude in regard to *time* is of the greatest importance. The usual practice has been for the observer to note the exact time of a transit or other phenomena, by listening to the beats of a clock or chronometer, and if an event should occur between two beats, to estimate the fraction of a second. To attain any proficiency in this branch, requires a nicety of hearing only to be acquired by long practice. By the electro-chronograph, the observer can record the *exact* time without taking his eye from the telescope.

If the toothed or electrical wheel be so adjusted as to let the tilt-hammer rest between the teeth during the current second, and be tripped only suddenly at every escape, the clock will be made to print lines representing seconds, thus—

Fig. 191.

Or, by reversing the action of the graver, the dots will be the length of the spaces in the above figure, thus—

Fig. 192.

But one of the sixty teeth is cut off; consequently, at every revolution of the wheel, which is once per minute, a line is produced as below—

In this manner are *minutes* marked on the fillet. Spaces of time equal to five minutes and the commencement of an hour are also marked in this way.

With one of these clocks, the difference of longitude between the National Observatory at Washington and any other point connected by telegraph, may be determined in one night so closely, as to show *in what part* of the observatory the observations were made. "And thus," in the words of Lieutenant Maury, "this problem, which has vexed astronomers and navigators and perplexed the world for ages, is reduced at once, by American ingenuity, to a form and method the most simple and accurate. While the process is so much simplified, the results are greatly refined. *In one night the longitude may now be determined with far more accuracy by means of the magnetic telegraph and clock, than it can by years of observation according to any other method that has ever been tried.*"

Dr. Locke, of Cincinnati, constructed a clock which enables the observer to record his observations by means of electro-magnetism. This clock interrupts the electric circuit at each second, and produces breaks which represent the circuit on a fillet of paper at the other end of the line. The dashes or lines between each break being exactly of the same length, each break represents a second. A wheel, consisting of sixty teeth, makes one revolution per minute. The handle of a small platinum tilt-hammer, resting on a bed of platinum, is struck by each tooth as the wheel revolves; this raises up the little tilt-hammer, which quickly resumes its place on the platinum bed. The fulcrum of the hammer and the platinum bed rest on a block of wood, and to each is attached one of the wires connected with a pole of the battery. By this contrivance, the electric circuit is alternately broken and formed by the rising and falling of the little hammer.

In the Washington Observatory, the pendulum is connected at its upper extremity with one of the wires from the battery; at the lower extremity of the pendulum is a fine metal point, which at every vibration passses through a globule of mercury placed in a small metal cup. A wire from the other pole of the battery is attached to the metal cup; so that when the pendulum touches the mercury, the circuit is complete, but is broken the moment the point of the pendulum is no longer in contact with it.

The lines between each break represent a second; and by an ingenious arrangement of the machinery, the end of each minute, each five minutes, and of each hour, may be recorded accurately. An astronomer at any station on a line of several thousand miles in length, may imprint on the register the date of any event, by simply tapping upon a *break-circuit key*. This imprints on the indented line a corresponding break-circuit space.

The clock in its ordinary movements causes the registering machine to mark an interrupted time scale on a running fillet of paper, (such as is used in a telegraph office.)

CHAPTER VI.

Graduated Circles.

There are several instruments comprehended under this head, of which the following are the most prominent:—The *Mural* circle, the *Transit* circle, the *Altitude* and *Azimuth* instrument, the *Sextant*, and the *Repeating* circle; but as our limits will not admit of full descriptions in this branch of astronomical science, we shall confine ourselves to the three first.

SECTION I.

The Mural Circle.*

This is an instrument which affords means of measuring arcs on the meridian. It consists of a circle of brass or other metal; and if for a large observatory, it should be about six feet in diameter. The mural circle is securely fixed to a perpendicular wall, (whence its name,) and is placed accurately in the plane of the meridian. The wall is composed of solid masonry, to insure steadiness of position. The axis of the circle is horizontal, and inserted into a stone pier, so that the plane of the circle may be in the plane of the meridian. The circle is connected with the central portion of the wheel by spokes or radii. These radii are composed of hollow cones, which are braced together by a set of bracing bars situated about midway between the centre and circumference of the wheel. The axis of the wheel is a cone of brass nearly 4 feet long, and 7 inches in diameter in the largest or front part of the cone, diminishing to about 3½ inches at the other extremity of the axis.

The telescope has a focal length of 6 feet 2 inches, the aperture is 4 inches, and the magnifying power about 150. At the focus of the telescope are vertical wires, which are illuminated by a diagonal reflecting plate, fixed in the middle of the tube, which receives the light through the circular aperture, exactly in a line with the centre of the circle, as shown in the following drawing.

A lantern at four or five feet distance, placed in the line of the axis, throws light on the field of view equal to the brightness of daylight, which light may be regulated and modified by means of colored glasses.

The limb of the circle consists of two rings, the inner one having its plane parallel, and the outer one its plane perpendicular, to the plane of the circle, so that when their edges are united, their section may form the figure of the letter T.

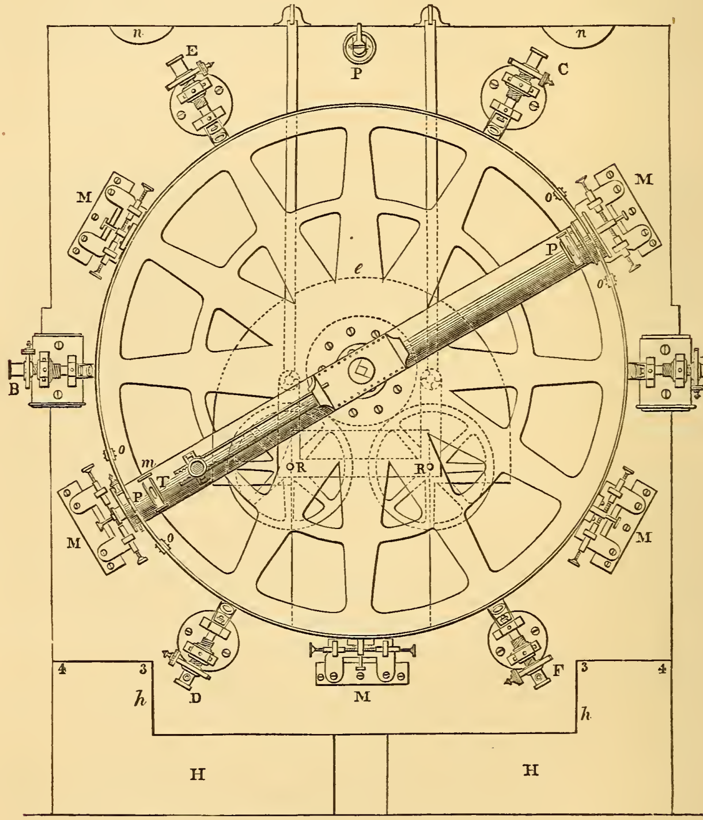
The graduation of this instrument is made on the broad surface of the exterior ring, which is at right angles to the plane of the circle. The divisions are made upon a narrow ring of white metal, composed of four parts of gold to one of palladium; and the figures which count the degrees are engraved upon a similar ring of platina; neither of these metals tarnish in the least, which renders frequent

---

* The description of this instrument, as well as of many others contained in this work, is taken from that admirable treatise, by the Rev. Dr. Pearson, entitled Practical Astronomy, 2 vols. 4to, 1 vol. plates.

cleaning of the surface unnecessary, as it would in time wear out the fine divisions. The divisions are by lines, not dots, and the degrees are cut into twelve parts or spaces of 5′ each, and are numbered from the pole southward round to the same pole again—viz. from 0° to 360°. The 5′ spaces are subdivided by the microscopes to single seconds, and a division representing this quantity on the micrometer head may easily be estimated to the tenth of a second.

Fig. 193.



WASHINGTON MURAL CIRCLE.

The mural circle at the observatory at Washington, of which the accompanying figure is a representation, is a circle of brass, five feet in diameter, having twelve T-barred spokes, which support a brass rim or *tire* four-tenths of an inch thick and two inches broad. The graduations are made in the periphery of this rim by lines parallel with the axis of the circle. The rim has two bands upon it—one in platina, on which the degrees are numbered from 1° to 360°; the other band is of gold, on which the subdivisions are made. These subdivisions are for every 5′

of arc, the divisions corresponding to a degree being designated by a large dot (•) at one end; those corresponding to 15′ by a smaller dot (.); those to 30′ by two dots (:); and those to 45′ by three dots (.·.).

In the figure, A B C D E F are reading microscopes, the wires of which for reading the instrument form with each other acute angles, which the divisions on the circle are made to bisect. The telescope is also furnished with a micrometer thread, which is parallel to the horizontal wire of the fixed diaphragm. The head of this micrometer is divided into 100 parts; readings therefore may, by subdivision, extend to thousandths of a revolution. The telescope is attached to an axis concentric with that of the circle, upon which it may be made to revolve independently of the circle. M M M M M are clamps with tangent screws, for slow motion. R R are friction rollers, supported by the flat rods *r r*, which are kept in action by the levers *l l*, having their compensating weights at the other end, to receive which weights a hole is cut in the top of the pier. T is the telescope, *m* the micrometer head; V is a milled-headed screw, working two rods with rachets, for regulating the illumination of the field by means of a square cut-off at the end of the rods; *o o* and *o o* are screws for securing the telescope at each end to the circle; *n* and *n* are scores cut for the more convenient reading of the microscopes C and E; P is the fixture for holding the plummet, which is suspended by a fine silver wire; and *p p* the *ghost* apparatus for levelling. H H is the bench for the artificial horizon, wrought out of the solid stone; between the figures 1 and 2 it is 9 inches thick, 12 inches from 2 to 3, and also 12 from 3 to 4. *h h* are steps on which the trough is placed for low stars; thus, an observation may be made by reflection without removing the basin of mercury from its bench. Nearly in the same plane with the wires of the reading microscopes, and visible through the eye-piece of each, is a scale like a saw, the distance between the teeth of which corresponds with the distance between the threads of the micrometer screw. Every fifth notch is deeper than the rest; the middle of the scale or zero-point of the microscope is designated by a round hole; and the notch which denotes the number of entire revolutions corresponding to a reading, is indicated by a little index or pointer attached for the purpose.

In the following figures the different parts of the reading microscope will be represented: *a* is a spider-line micrometer, with one screw; *b* (*figs.* 194 and 196) is a tube, two inches long, having a screw on the exterior face and one on the interior; it is screwed to the lower plate of the micrometer, and at right angles to it; *c* is the cock to which a short tube of half an inch in length is fixed, that admits the tube *b* just to pass into it; *d d* are two circular nuts, with milled heads; the use of these nuts is to fix the tube *b* in any required position; *e* is the cell that receives the eye-piece, and screws into the outer plate of the micrometer; *g* is a cone of brass, holding the object-lens at its inferior end, the other end being screwed into the body of the tube *b*; *h* (*figs.* 194 and 196) is a small cell that holds the object-lens; *i* is a third circular nut, with a milled head, by means of which the distance of the object-lens may be graduated. The two pieces of *fig.* 195 lie over one another in the oblong box, *fig.* 197; one having the scale of notches on the edge of its large opening, and the other carrying the crossed spider lines, immediately above the said scale. As they both fit the sides of the

box, they are thus kept parallel to one another when moved separately over each other. The fork, having its prongs connected by an end-piece *k*, is moved by means of the milled nut and divided head, seen in *fig.* 194; and the crossed lines and included piece of wire forming an index to the notches, travel over the scale *m*, the place of which is adjusted by a small screw *n* passing through an X spring, as shown in *fig.* 197. A strong pin rises from the under side of the oblong box *o*, (*fig.* 197,) and passing within the fork and slit made at *p* through the plate carrying the notched scale, presents its upper end to the small spiral spring which, acting in opposition to the micrometer's screw *l*, prevents any loss of motion in turning it. The fixed piece *q* (*figs.* 194 and 196) is the index to the divided head *r*, turning with the screw, and showing exact seconds.

Fig. 194.

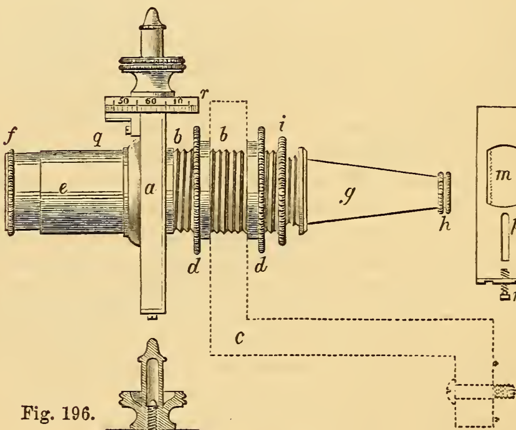


Fig. 195.

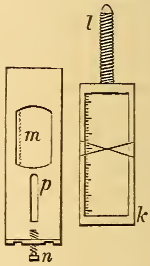


Fig. 196.

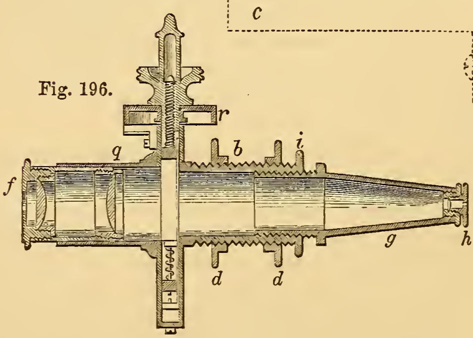
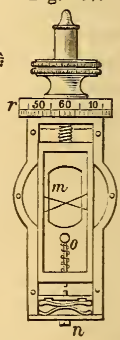


Fig. 197.



SECTION II.

The Transit Circle.

The object of the transit circle is to give the right ascensions as well as the declinations of stars at the same time. This instrument consists of two circular rings or wheels, the spokes of which are formed of two sets of hollow cones; the

two wheels are united together by various bars crossing each other. Each of these wheels is divided or graduated into four quadrants, by spaces of 5′. The axis of the wheels is supported by two stone piers, which have their perpendicular and parallel faces separated about 27 inches. To the interior face of each pier, just below their summits, is a strong horizontal bar of brass made fast, the extreme ends of which are turned up so as each may hold a pair of microscopes for reading the divisions at the opposite ends of the horizontal diameter of the circle, to which they are capable of being adjusted. The zenith distance or altitude may be read on the circles, and at the same time a transit may be taken in the usual way, by the system of spider lines that are fixed in the common focal point of the object-glass and eye-piece. Hence, it is obvious that, by the proper use of this instrument, a star or other heavenly body may have its place referred both to a circle of declination and to the equator, at the same instant.

SECTION III.

Altitude and Azimuth Instrument.

The chief use of this instrument is to find the altitude and azimuth of a star; or, to observe the Moon when in those portions of her orbit too near to the Sun to be observed on the meridian; her proximity to that luminary for two or three days before and after her conjunction, rendering her invisible when on the meridian.

This instrument is composed of a horizontal and a vertical axis, to each of which is attached a graduated circle. That circle which moves in a horizontal plane is the azimuth circle; and that moving in a vertical plane is called the vertical circle. The vertical circle consists of two circles connected together by small brass bars. The side of one of the circles is inlaid with a ring of silver, on which the graduation is made. The azimuth circle, or that which moves in the plane of the horizon, is graduated and read off by means of two reading microscopes. The telescope is attached to the horizontal axis, somewhat like that of the transit instrument. The vertical circles are placed close to the telescope, and are read by means of two microscopes attached to two pieces of metal fastened near the top of one of the pillars which support the horizontal axis of the instrument. The spider-lines in the telescope are illuminated after the manner of the transit instrument.

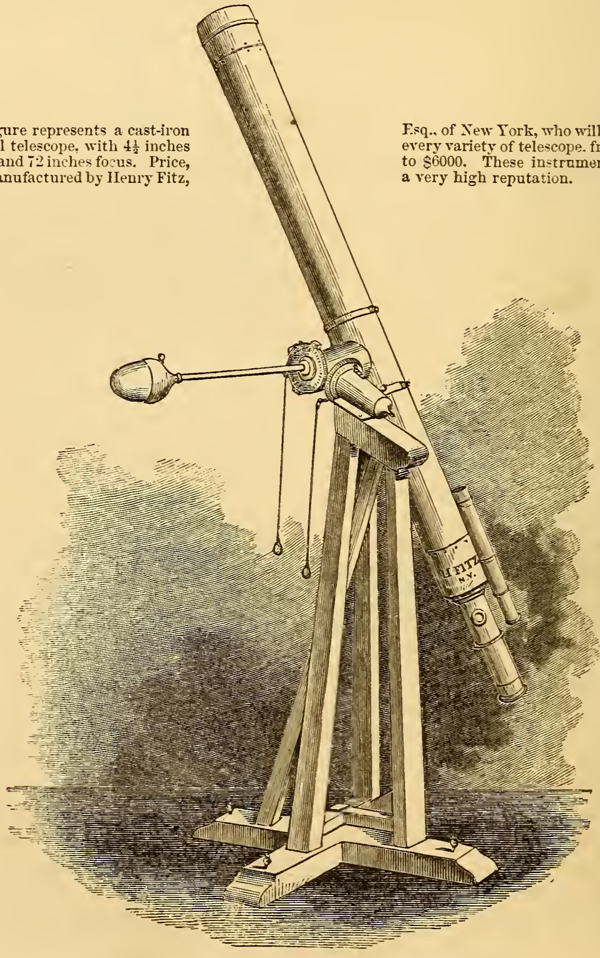
To adjust the instrument, it is necessary to level the horizontal or azimuth circle, and also the axis of the telescope, as in the transit instrument. When the telescope is directed north and south, the meridianal point on the azimuth circle may be determined by observing a star at equal altitudes from the meridian, east or west, and determining the point exactly between the two observed azimuths. The instrument may be adjusted to the meridian in the same manner as for the transit instrument. The horizontal point of the altitude circle is its reading when the axis of the telescope is horizontal, and may be found as with the mural circle, by alternate observations of a star direct, and reflected from the surface of mercury.

There are many other astronomical instruments in use in observatories, besides those above described, which the student may find fully explained and elegantly illustrated in that great work, "Practical Astronomy," by the Rev. W. Pearson.

Many of the modern instruments may also be found in the works on Practical Astronomy by Professor Loomis, Dr. Dick, and others.

The grand attainments in the various branches of astronomy have not been acquired by any one individual, but are the combined efforts of all former ages; thus contributing to our mental instruction and moral improvement, as if seen with our own eyes, heard with our own ears, and handled with our own hands, from the earliest periods on record. From age to age our mass of knowledge is continually increasing, as well as our facilities for further investigations. Let each one, therefore, contribute his mite to the general stock, for the benefit of those who are to come after us.

This figure represents a cast-iron equatorial telescope, with $4\frac{1}{4}$ inches aperture and 72 inches focus. Price, $300. Manufactured by Henry Fitz, Esq., of New York, who will furnish every variety of telescope, from $125 to $6000. These instruments have a very high reputation.



PART V.

Treatise on the Globes.

The following problems are designed to familiarize the student with the principles of Geography and Uranography, in connection with the phenomena of the heavenly bodies.

CHAPTER I.

Problems on the Terrestrial Globe.

PROBLEM I.

To find the latitude and longitude of any place.

Rule.—Bring the given place to the graduated side of the brass meridian; the degree of the meridian directly over the place shows the latitude, and the degree on the equator cut by the brass meridian shows the longitude.*

EXAMPLES.

1. What is the latitude and longitude of Washington?
Ans. Lat. 38° 53′ north, lon. 77° 15′ west.
2. What is the latitude and longitude of the Cape of Good Hope?
Ans. Lat. 33° 56′ south, lon. 18° 23′ east.

Required the latitudes and longitudes of the following places:

3. Boston.
4. Canton.
5. London.
6. Cairo.
7. Cincinnati.
8. Glasgow.
9. Gottingen.
10. Paris.
11. San Francisco.
12. Rome.

PROBLEM II.

To find any place on the globe, the latitude and longitude of which are given.

Rule.—Bring the given longitude to the meridian, then under the given latitude, on the brass meridian, will be found the place required.

* The longitudes are reckoned from the meridian of Greenwich.

EXAMPLES.

1. Find the place which is situated in lat. 57° 8′ N., and lon. 2° 10′ W.

2. What place is situated in lat. 39° 57′ N., and lon. 75° 7′ W.?

Find those places having the latitudes and longitudes as follows:

3.	Lat. 41° 1′ N.	Lon. 28° 55′ E.
4.	53° 23′ N.	6° 20′ W.
5.	19° 0′ S.	174° 0′ W.
6.	43° 17′ N.	5° 22′ E.
7.	22° 53′ S.	43° 12′ W.

8. Find all those places which have no latitude.

9. Find those places which have no longitude.

PROBLEM III.

To find the difference of latitude between any two places.

Rule.—Find the latitude of both places, and the number of degrees between them reckoned on the brass meridian will be the difference of latitude. Or find the latitudes of both places, and if they be of the same name—that is, both north or both south—their difference is the difference of latitude; but if one is north latitude and the other south, their sum will be the difference of latitude.

EXAMPLES.

1. What is the difference of latitude between Washington and Berlin? *Ans.* 13° 38′.

2. What is the difference of latitude between London and the Cape of Good Hope? *Ans.* 85° 27′.

What is the difference of latitude between the following places?

3. Lisbon and Rio Janeiro.
4. St. Petersburg and Calcutta.
5. Cape Horn and Cape of Good Hope.
6. Isthmus of Darien and Isthmus of Suez.
7. Quito and Philadelphia.
8. North Pole and the South Pole.

PROBLEM IV.

To find the difference of longitude between any two places.

Rule.—Bring one of the given places to the brass meridian, and find what degree of the equator is cut by it; then bring the other place to the brass meridian, and the number of degrees counted on the equator the shortest distance between the two, will show the difference of longitude. Or, after finding the longitudes of both places, if they be of the same name—that is, if both be east or both be west—their difference is the difference of

longitude; but if they be of different names, their sum will give the difference of longitude.

EXAMPLES.

1. What is the difference of longitude between Bremen and New York? *Ans.* 65° 11′.

Find the difference of longitude between the following places:

2. Cadiz and Cincinnati.
3. Savannah and Alexandria.
4. Athens and Quebec.
5. St. Petersburg and Nova Zembla.
6. Paris and Baltimore.

PROBLEM V.

To find the difference of time between two places.

RULE.—Find the difference of longitude as in the last problem, and divide the number of degrees thus ascertained by 15.

EXAMPLES.

1. What is the difference of time between Philadelphia and Liverpool? *Ans.* 4*h.* 48*m.* 52*s.*

Therefore, when it is noon at Liverpool, it is 4*h.* 48*m.* 52*s.* before noon, or 7*h.* 11*m.* 8*s.* in the morning at Philadelphia; because Liverpool lies east of Philadelphia, the sun rises at that place first.

2. When it is 10 o'clock in the morning at Paris, what is the time at Philadelphia?

Ans. 49*m.* and 56*s.* past 4 in the morning.

3. When it is noon at Montreal, what time is it at Canton?
4. What is the difference of time between London and New Orleans.
5. When it is 6 o'clock A. M. at Quito, what time is at Constantinople?
6. When it is midnight at Calcutta, what time is it at Boston?
7. When it is noon at Paris, what time is it at San Francisco?

PROBLEM VI.

To find all those places which have the same latitude as any given place.

RULE.—Bring the place to the brass meridian, turn the globe, and all those places which pass under the same degree of the brass meridian as the given place have the same latitude.

EXAMPLES.

1. What places have the same latitude as St. Louis?

Ans. Frankfort, Ky.; Portsmouth, Ohio; Pico, one of the Azores; Murcia, in Spain; Malta; Palermo; Pekin; Kingkitao; and Shanday.

Find all those places which have the same latitude as the following:

2. Charleston.
3. Quito.
4. San Francisco.
5. Truxillo.
6. Mount Heckla.
7. Sierra Leone.
8. London.

PROBLEM VII.

To find those places which have the same longitude as any given place.

RULE.—Bring the place to the brass meridian; those places situated under the same edge of the brass meridian have the same longitude.

EXAMPLES.

1. What places have the same longitude as Boston?

Ans. Whale Sound and Quebec, in North America; and Coro, Cuzco, Copiapo, Totora, Coquimbo, and Valparaiso, in South America.

2. What places have the same longitude as New Orleans?
3. Calcutta?
4. St. Petersburg?
5. City of Mexico?
6. Mecca?

Those places which have the same longitude have the same hour of the day.

7. What places have their noon the same time as at Paris?
8. What places have the same time as Rome?

PROBLEM VIII.

To find the antœci of any place.

RULE.—Bring the given place to the brass meridian and find its latitude; then under the same meridian, and in the same degree of latitude in the opposite hemisphere, you will find the antœci.

EXAMPLES.

Required the antœci of the following places:

1. New York. *Ans.* Valdivia, in South America.
2. Juan Fernandez. *Ans.* Charleston.
3. Boston.
4. Azof.

The antœci have the same hours, but contrary seasons of the year; thus, it is noon with both at the same time, but winter with one when it is summer with the other.

5. Required those places whose seasons are directly opposite to those of Quebec.
6. Malta.
7. Bermudas.
8. Potosi, South America.
9. Rome.

PROBLEM IX.

To find the antipodes of a given place.

RULE.—Bring the place to the brass meridian, mark the latitude, and set the index to 12; turn the globe till the index has passed over 12 hours, then count as many degrees of latitude towards the contrary pole as are equal to the latitude of the place; this point will be the antipodes of the given place. Or, bring the given place to the horizon, and the opposite point of the horizon will be the antipodes.

EXAMPLES.

1. Find the antipodes of Oporto.

Ans. Cook Straits, island of New Zealand.

2. A ship in the Indian Ocean found its latitude was 9° S., and longitude 101° E. from Greenwich: where are its antipodes?

Ans. Panama.

3. Where are the antipodes of the Friendly Isles?

4. Suppose a line were to be drawn through the centre of the Earth from a point in the Southern Ocean, lat. 40° S., and lon. 105° E. from Greenwich: what place on the surface would it touch on the opposite side?

5. What places on the Earth are the seasons and hours contrary to those of Washington City?

PROBLEM X.

To find the perioeci of a given place.

RULE.—Bring the given place to the brass meridian, note the latitude, and set the index to 12; turn the globe till the index has passed over 12 hours. The place under the same degree of latitude is the perioeci required.

EXAMPLES.

1. Required the perioeci of Merida, in Yucatan.

Ans. The mouths of the Ganges.

2. What place has the same seasons as Astoria, but contrary hours; that is, when it is noon at one, it is midnight at the other place? *Ans.* The northern part of the Sea of Aral.

Required the perioeci of the following places:

3. Cape May.
4. St. Petersburg.
5. Buenos Ayres.
6. Constantinople.
7. Rome.
8. Vera Cruz.

PROBLEM XI.

To find the distance between two places.

RULE.—When the distance is less than 90°, lay the quadrant

of altitude over both places, so that the division marked 0 may be over one of them; the degree cut by the other place will show the distance in degrees, which can be reduced to miles by multiplying them by $69\frac{1}{2}$, because $69\frac{1}{2}$ miles make one degree. But when the distance is more than 90°, subtract the distance from 180, and the remainder will be the distance required.

EXAMPLES.

1. Required the distance between Philadelphia and Calcutta. *Ans.* 7831 miles.
2. Philadelphia and Liverpool. *Ans.* 50°, or 3484 miles.
3. Philadelphia and New Orleans.
4. Philadelphia and San Francisco.
5. What is the length of the United States from the northern point of Maine to Florida Keys?
6. What is the distance between Paris and the Crimea?
7. London and St. Petersburg.
8. Rome and Jerusalem.
9. Madras and Lisbon.
10. How many miles will be travelled over in the following route?—From Washington City to Cincinnati, Nashville, St. Louis, Chicago, Niagara, Albany, Boston, and Philadelphia.

PROBLEM XII.

The hour being given in any place, to find what hour it is in any part of the world.

RULE.—Bring the given place to the meridian, and set the index to the given hour; then turn the globe till the other place comes to the meridian, and the index will show the time required.

EXAMPLES.

1. When it is noon at Washington City, what o'clock is it at London? *Ans.* 5*h.* 7*m.* P. M.

The above problem can be solved without the globe, thus:—Find the difference of longitude between the two places in degrees, and reduce it to time by multiplying the degrees and minutes by 4; the product will be minutes and seconds. Or divide the number of degrees by 15 for the answer in hours, and if there be a remainder, multiply it by 4 for the minutes.

The difference of longitude in time will be the difference of time between the two places. If the place at which the time is required be *east* of the place at which the time is given, the time required will be *later* than the given time; but if the place at which the time is required be *west* of the place at which the time is given, the required time will be *earlier* than the given time.

In the above question it is required to know what time it is at

London when it is 12 o'clock at Washington. Now, as London, the place at which the time is required, is *east* of Washington, the time required must be later than 12 o'clock, the given time.

The problem is solved by calculation, thus:

$$
\begin{array}{rl}
77^\circ\ 3'\ \mathrm{W} & = \text{lon. Washington.} \\
9\ \ \mathrm{W} & = \text{lon. London.} \\
\hline
76\ 54\ \ \ & = \text{difference of lon.} \\
4\ \ \ & \\
\hline
60)\underline{307\ 36}\ \ \ &
\end{array}
$$

5h. 7m. 36s. the difference of time between the two places. Consequently, when it is noon at Washington, it is *5h. 7m. 36s.* P. M. at London, because it lies east of Washington; and therefore the time must be later.

3. When it is 6 A. M. at Paris, what time is it at Constantinople?
4. When it is midnight at New York, at what places is it noon?
5. When it is 4 A. M. at Charleston, what time is it at Calcutta?
6. What hour is it at Boston, when it is 10 o'clock A. M. at London?

	GIVEN TIME.	PLACE AT WHICH TIME IS GIVEN.	PLACE WHERE TIME IS REQUIRED.
7.	7 A. M.	St. Louis.	Berlin.
8.	5 P. M.	San Francisco.	Philadelphia.
9.	Noon.	Quito.	Borneo.
10.	11 P. M.	Gottingen.	Algiers.
11.	8 P. M.	Ispahan.	Fort Churchill.
12.	9 A. M.	Corinth.	Truxillo.

PROBLEM XIII.

The day of the month being given, to find the Sun's place in the ecliptic.

RULE.—Find the given day in the circle of months on the wooden horizon, and opposite to it in the circle of signs are the sign and degree which the Sun occupies on that day. Find the sign and degree on the ecliptic on the globe, and bring the degree of the ecliptic thus found to that part of the brass meridian which is numbered from the equator to the poles; then that degree of the meridian which is over the Sun's place is the declination required. Or,

By the Analemma.

Bring the analemma to the brass meridian, and the degree cut on it directly above the given day of the month is the Sun's declination. Bring that part of the ecliptic which corresponds with the given day under this degree of the Sun's declination, and that point will be the Sun's place in the ecliptic, or his longitude for that day.

EXAMPLES.

1. Required the Sun's longitude and declination on the 12th of May. *Ans.* 21° 45′; in ♉ dec. 18° N.

What is the Sun's longitude and declination on the following days?—

2. June 30.
3. May 19.
4. January 1.
5. Christmas-day.
6. March 3.
7. November 12.
8. February 22.
9. August 6.

PROBLEM XIV.

To rectify the globe for the Sun's place on a given day.

Rule.—Find the Sun's declination for the given day, and bring his place to the brass meridian; elevate the pole which is of the same name as the declination; that is, if the declination is north, elevate the north pole, and if it be south, the south pole. The pole should be elevated as many degrees as are equal to the declination.

When the globe is thus rectified, all those places above the wooden horizon will be in the enjoyment of day; and those places below it will be in darkness, or night.

EXAMPLES.

1. Rectify the Globe for the Sun's place on the 1st of June.

Ans. The Sun's declination on the 1st of June is 22° N.; therefore the north pole must be elevated 22°, and all those places situated within 22° of the north pole must have continual day, while to those situated within 22° of the south pole there is no sunlight.

2. Rectify the globe for the Sun's place on the 22d of December.

Ans. The Sun's declination on the 22d of December is 23° 30′ S.; therefore the south pole must be elevated; and to all places situated within the Arctic Circle, which is 23° 30′ of the north pole, the Sun does not rise, while to those places situated within the Antarctic Circle, he never sets.

3. Rectify the globe for the 21st of September.
4. For the 1st of May.
5. For the 23d of March.
6. For the 16th of August.

PROBLEM XV.

To find the time of the Sun's rising and setting, and the length of the day and night at any place.

Rule.—Elevate the pole according to the latitude of the place, bring the Sun's place to the meridian, and set the index to 12.

Then bring the Sun's place to the eastern horizon, and the index will show the time of the Sun's rising; when the Sun's place is brought to the western horizon, it shows the time of his setting.

EXAMPLES.

1. What time does the Sun rise and set in New York on the 10th of May? *Ans.* The Sun rises at 5, and sets at 7.

The length of the day is found by multiplying the time of sunsetting by 2, and the length of the night by doubling the time of sunrising. Also, the length of the night taken from 24 will give the length of the day, and *vice versâ.* Moreover, half the length of the day gives the time of sunsetting, and half the length of the night the time of sunrising.

The length of the day at New York on the 10th of May is 14 hours, and the length of the night 10 hours.

2. What time does the Sun rise and set at London on the 1st of December? and what is the length of the day and night?

Ans. The Sun rises at 8*h.* 40*m.*, and sets at 3*h.* 20*m.*

3. At what time does the Sun rise and set at every place on the globe on the 21st of March and on the 23d of September? and what is the length of the day?

Ans. It rises at 6 and sets at 6, and the day is 12 hours long.

Which is the longest day at the following places?—

4. London.
5. Quito.
6. Terra del Fuego.
7. Melville Island.

Required the shortest day at the following places:

8. Disco Island, in Davis Strait.
9. Stockholm.
10. Vienna.
11. Rio Janeiro.
12. Pekin.
13. Astracan.

PROBLEM XVI.

To find the Sun's meridian altitude for any day.

RULE.—Elevate the globe for the latitude of the given place; find the Sun's place for the given day, and bring it to the brass meridian. Fix the quadrant of altitude on the zenith, and bring it over the Sun's place; then the degree upon the quadrant cut by the Sun's place will be its meridian altitude.

EXAMPLES.

1. What is the Sun's meridian altitude at Washington City on the 21st of June? *Ans.* 74° 35′.

2. What is the Sun's meridian altitude at Charleston on the shortest day in the year?

3. What is the Sun's meridian altitude at Berlin on the 4th of July?

4. What is the Sun's meridian altitude at the Cape of Good Hope on the 10th of February?

5. What is the Sun's meridian altitude at Melville Island on the 1st of July?

What is the Sun's meridian altitude at the following places?—

6. Quito, on the 8th of May.
7. Pernambuco, on the 12th of June.
8. Truxillo, on the 15th of September.
9. Samarcand, on the 8th of August.
10. Quebec, on the 4th of January.
11. Aleppo, on the 3d of March.
12. Cairo, on the 19th of December.

PROBLEM XVII.

To find the Sun's altitude for any hour, having the latitude and the day of the month given.

Rule.—Rectify the globe for the latitude, screw the quadrant of altitude over the zenith, bring the Sun's place for the given day to the brass meridian, and set the index to 12. Turn the globe till the index points out the given hour, bring the graduated edge of the quadrant over the Sun's place, and the degree cut on it will be the Sun's altitude. Or, elevate the pole to the Sun's declination, screw the quadrant of altitude in the zenith, bring the given place to the brass meridian, and set the index to 12. If the given hour be in the forenoon, turn the globe westward; but if it be in the afternoon, turn it eastward, as many hours as the time is before or after 12; bring the quadrant of altitude over the given place, and the degree cut on it will be the Sun's altitude.

EXAMPLES.

1. What is the altitude of the Sun at St. Petersburg on the 21st of March, at noon? *Ans.* 60°.

2. Required the altitude of the Sun at the City of Mexico on December 5, at 7 A. M.? *Ans.* 6°.

3. What is the Sun's altitude at Sydney on the 12th of April, at 11 A. M.?

4. What is the Sun's altitude at St. Helena on the 5th of August, at 3 P. M.?

5. What is the Sun's altitude at Spitzbergen, June 21, at midnight?

6. What is the Sun's altitude at Boston on September 3, at 4 P. M.?

PROBLEM XVIII.

To find all those places where the Sun has the same altitude as any given place, at any given time.

Rule.—Find where the Sun is vertical at the given time—that

is, find his declination—bring the given place to the brass meridian, and set the index to the given hour; if the hour be in the forenoon, turn the globe westward; and if in the afternoon, turn it eastward, until the index points to 12. Mark the places exactly under the Sun's declination, and then place the degree of the quadrant of altitude marked 0° over the place thus found: all those places the same distance from it as the given place will be the places required. Those places situated at the same distance from it as the given place may be found by holding the part of the quadrant marked 0° on the place found, and then turning it round: the places which come under the same degree of the quadrant as the given place will be the same distance from that found.

EXAMPLES.

1. When it is 10 o'clock in the morning at Washington City on the 5th of May, required all those places where the Sun, at that moment, will have the same altitude as at Washington.

Ans. The place where the Sun will then be vertical is lat. 16° N., lon. 47° W. from Greenwich; and those places which are at the same distance from it as Washington, are—Quito; Sierra Leone; Providence, R. I.; Baltimore; Columbia, S. C.; St. Mary's, Fla.

2. When it is 4 o'clock in the afternoon at Paris, on the 10th of August, find all those places where the Sun will have the same altitude as at Paris.

3. Find all those places where the Sun will have the same altitude as at New Orleans on the 21st of September, at 11 o'clock.

4. Name all those places where the Sun will have the same altitude as at Mecca on the 4th of July, at 7 o'clock, A. M.

PROBLEM XIX.

Having the Sun's meridian altitude, to find the latitude of the place.

RULE.—Bring the Sun's place to the brass meridian, and mark his declination. Note as many degrees on the brass meridian from this point as is equal to the given altitude—reckoning towards the south, if the Sun be south of the observer, and towards the north, if he be north of the observer. Bring the degree where the reckoning ends to coincide with the horizon, and the number of degrees the elevated pole is from the horizon is the latitude required. Or, by calculation, thus:—Subtract the given altitude of the Sun from 90°; the remainder will equal the zenith distance, which is north if the zenith be north of the Sun, or south if the zenith be south of it; take the Sun's declination from the table for the given day, and observe whether it be north or south; then if the zenith distance and declination be both north or

both south, add them together; but if one be north and the other south, subtract the lesser from the greater, and the sum or difference will be the latitude of the same name with the greater.

EXAMPLES.

1. On the 8th of October the meridian altitude of the Sun was found to be 20° S., the observer being north of the Sun: required the latitude of the place of observation. *Ans.* 64° 14′ N.

By Calculation.

	90° 0′	
	20 0	
	70 0	zenith distance N.
Subtract	5 46	Sun's declination S.
	64 14	N. lat.

2. What is the latitude of that place at which the Sun's meridian altitude on the 19th of October was found to be 8° 20′ S.? *Ans.* 71° 47′ N.

3. What is the latitude of that place at which the Sun's meridian altitude on the 30th of May was observed to be 49° 25′ N.? *Ans.* 18° 45′ S.

4. The Sun's meridian altitude on the 10th of May was observed to be 40° S.: what was the latitude of the observer?

5. On the 12th of July the Sun's meridian altitude was observed to be 50° 30′ N.: what was the latitude?

6. The meridian altitude of the Sun was observed to be 32° 15′ S. on the 21st of March: what was the latitude?

PROBLEM XX.

To find when the Sun is due east or west, the latitude of the place and the day of the month being given.

Rule.—Elevate the globe for the latitude, bring the Sun's place to the meridian, and set the index to 12. Screw the quadrant of altitude on the zenith. If the Sun's declination and the latitude be both north or both south, bring the quadrant to the *eastern* point of the horizon; but if the Sun's declination and the latitude be not of the same name—that is, if one be north and the other south—bring the quadrant of altitude to the *western* point of the horizon. Turn the globe till the point of the ecliptic denoting the Sun's place come to the edge of the quadrant, and the index will show the time required. Subtract the hour when the Sun is due east, from 12, for the time when he is due west, and the reverse.

EXAMPLES.

1. When is the Sun due east and west at Tripoli, August 15? *Ans.* E. 7*h.* 10*m.*; W. 4*h.* 50*m.*

2. When is the Sun due east at Montreal on the 5th of July? and at what hour will he be due west?

Ans. E. 8*h.* 10*m.*; W. 3*h.* 50*m.*

3. At what hours will the Sun be due east and west at London on the 21st of June?

4. At what hours will the Sun be due east and west at Gibraltar on the 21st of September?

5. At the Cape of Good Hope, February 1?

6. At Prince of Wales Island, north-west coast of North America, on the 1st of February?

7. When will the Sun be due west at Cincinnati on the 20th of October?

PROBLEM XXI.

To find on what two days of the year the Sun is vertical at any given place in the torrid zone.

RULE.—Bring the given place to the brass meridian, and mark its latitude. Then turn the globe on its axis, and observe the two points of the ecliptic which pass under that latitude. Find those points of the ecliptic in the circle of signs on the wooden horizon, and exactly opposite to them in the circle of months will be found the days required. Or, having found the latitude of the place, bring the analemma to the meridian, upon which, exactly below the latitude, will be found the days required.

EXAMPLES.

1. On what two days will the Sun be vertical at Cape Verd?

Ans. May 1, and Aug. 11.

2. On what two days will the Sun be vertical at Cuzco, in Peru? *Ans.* Feb. 13, and Oct. 28.

On what days will the Sun be vertical at the following places?—

3. Borneo.
4. Quito.
5. Rio Janeiro.
6. Guadaloupe.
7. Vera Cruz.
8. St. Helena.
9. Owyhee.
10. Seringapatam.
11. Batavia.

PROBLEM XXII.

The day being given, at any place not in the frigid zones, to find what other day of the year is of the same length.

RULE.—Find the Sun's place in the ecliptic for the given day, bring it to the brass meridian, and observe the degree above it; turn the globe on its axis, and observe what other point of the ecliptic falls under the same degree of the brass meridian: find

this degree of the ecliptic marked on the wooden horizon, and exactly opposite to it will be the day of the month required.

By the Analemma.

Bring the given day on the analemma to the meridian, and on the other half of the analemma will be the day required.

EXAMPLES.

1. What day of the year is of the same length as the 30th of January? *Ans.* November 11.
2. What day is of the same length as the 25th of April? *Ans.* 18th of August.
3. What day is of the same length as the 10th of November?
4. If the Sun rise at Philadelphia on the 5th of August at 5 o'clock in the morning, what other day will it rise at the same hour?
5. If the Sun is vertical at any place on the 12th of June, how many days must elapse before he is again vertical at that place?
6. If the Sun rise at Gottingen at 4 o'clock in the morning on the 20th of July, on what other day will he rise at the same hour?

PROBLEM XXIII.

The day and hour being given for any place, to find where the Sun is then vertical.

RULE.—Find the Sun's declination, bring the given place to the brass meridian, and set the index to 12. If the given time be before noon, turn the globe *westward* as many hours as it wants of noon; but if it be past noon, the globe should be turned *eastward* as many hours as the time is past noon: the place exactly under the degree of the Sun's declination will be that which is required.

EXAMPLES.

1. When it is 2 o'clock in the morning in Washington on the 28th of July, where is the Sun at that instant vertical? *Ans.* At Poonah, in India.
2. When it is half-past seven at Jerusalem on the 24th of October, where is the Sun then vertical? *Ans.* At Lima, in Peru.
3. When it is 9 A. M. at Dublin, February 12, where is the Sun vertical?
4. At London, December 21, at 2 o'clock A. M.: where is the Sun then vertical?
5. When it is 1*h.* 53*m.* at Amsterdam on the 30th of April, where is the Sun vertical?

6. At the Cape of Good Hope, when it is $1h. 37m.$ on the 6th of November, where is the Sun at that moment vertical?

PROBLEM XXIV.

The day and hour having been given at any place, to find where the Sun is rising, setting, where it is noon, those places that have the morning twilight, those having evening twilight, and those places where it is midnight at that time.

RULE.—Find the place where the Sun is then vertical, elevate the globe for that place, and bring it to the meridian. All those places along the western edge of the wooden horizon have the Sun rising; to those along the eastern edge, he is setting; those under the brass meridian, above the horizon, have noon; those under the brass meridian, below the horizon, have midnight; that particular point under the degree of the Sun's declination on the brass meridian, has the Sun vertical; all those places situated within eighteen degrees below the eastern edge of the horizon, have evening twilight; and those situated within eighteen degrees below the western edge of the horizon, have morning twilight.

EXAMPLES.

1. When it is 10 o'clock in the morning at St. Louis on the 5th of August, where is the Sun then rising?

Ans. At Kamschatka, the Sandwich Islands, and the Georgian Islands.

Where is he then setting?

Ans. Siberia, Sea of Aral, southern part of the Caspian Sea, Bassora, middle of the Red Sea, and middle of Africa.

Where is he then vertical?

Ans. At the island of Antigua.

Where is it then noon?

Ans. At Baffin's Bay, Labrador, Nova Scotia, Carribee Islands, mouths of the Orinoco, middle of South America, and Falkland Islands.

At what places is it then midnight?

Ans. Middle of Siberia, eastern part of China, eastern part of the islands of Borneo and Java, and the western part of New Holland.

Where is it morning twilight?

Ans. Those islands in the Pacific Ocean between the Sanwich and Mulgrave Islands, and between the Georgian and Friendly Islands.

Where is it evening twilight at that time?

Ans. Tartary, Persia, eastern part of Arabia, and eastern coast of Africa.

2. When it is 2 o'clock in the morning at St. Michael's, one of the Azores, on the 27th of July, at what places is the Sun rising and setting at that time? Where is he vertical? What places have noon? What have midnight?

3. At Edinburgh at 6 A. M., where is it noon? sunrise? sunset? midnight? and where is the Sun vertical?

4. At Charleston at noon, where is the Sun vertical? where is it rising? setting? and where is it midnight?

5. At midnight at Philadelphia, where is the Sun vertical? where is it rising? setting? and where is it noon?

PROBLEM XXV.

A place being given in the north frigid zone, to find the length of the longest day and night there; likewise the first and last days of his appearance.

RULE.—Subtract the latitude from 90°, which is the co-latitude, and reckon an equal number of degrees on the brass meridian from the equator, north and south; under the points where the reckoning ends, bring that point of the ecliptic between Aries and Cancer, and observe what point of it passes under the above mark on the brass meridian; this point will give the Sun's place when the longest day commences. Turn the globe westward, and observe the next point of the ecliptic which comes under the degree of the brass meridian thus marked; this point will give the Sun's place when the longest day ends, and the day corresponding to it will be the last day on which the Sun will constantly shine without setting. The number of days between the two will be the length of the longest day in the given place. Turn the globe westward again, and mark the point of the ecliptic that comes under the degree on the brass meridian, situated below the equator, which is equal to the co-latitude which was found; this point will give the Sun's place corresponding to the last day of his appearance above the horizon, or the beginning of the longest night. Turn the globe westward again, and observe the next point of the ecliptic which falls under the same degree; this will be the Sun's place when the longest night ends. The number of days between the end of the longest day and the beginning of the longest night, together with the number of days from the end of the longest night to the beginning of the longest day, will be those days on which the Sun will rise and set alternately every 24 hours.

By the Analemma.

The two days on the analemma that pass under the *co-latitude* on the brass meridian north of the equator, will be the beginning

and end of the longest day; and those two days that pass under the *co-latitude* south of the equator, will be the beginning and end of the longest night.

By Calculation.

Subtract the latitude from 90°, and the remainder will be the *co-latitude.* The Sun being in the ascending signs, find by the table on what day his declination is equal to the co-latitude, but of a *contrary* name; this will denote the day when the Sun first appears above the horizon: find the same when the Sun is in one of the descending signs; this will be the day on which he entirely disappears. In the same manner, find the two days when the Sun's declination is equal to the co-latitude, and of the same name with it: the one will be the beginning, the other the end, of the longest day.

EXAMPLES.

1. When does the Sun begin to appear above the horizon at the island of Jan Mayen, lat. 71° 10′? when does it disappear? how many days are the inhabitants without seeing the Sun? and what is the length of their longest day?

Ans. The co-latitude is 18° 50′; this being counted on the brass meridian on both sides of the equator, the four points of the ecliptic that pass under it will correspond to May 15, July 28, November 14, and January 26. Consequently, the longest day begins on the 15th of May and ends on the 28th of July, and is therefore equal to 74 days of 24 hours each. The longest night commences on the 14th of November and ends on the 26th of January, and is therefore 73 days long, during which time the inhabitants do not see the Sun.

2. What is the length of the longest day and longest night on the northern part of the island of Spitzbergen, in lat. 80° N.? when do they begin and end?

Ans. The longest day begins on the 15th of April, and ends on the 27th of August. The longest night commences on the 18th of October, and ends on the 22d of February.

3. What is the length of the longest day and longest night at the North and South Poles? when do they commence? and what is the difference between the summer and winter half year at both poles?

4. What is the length of the longest day and longest night at Mount Heckla, in Iceland?

5. What is the length of the longest day and night at Melville Island?

PROBLEM XXVI.

To find in what latitude in the frigid zone the Sun begins to shine without setting on any given day.

Rule.—Find the Sun's declination for the given day by the

table, and subtract it from 90°; the remainder will be the latitude required. For the north frigid zone the given day must be between the vernal equinox and summer solstice, or from the 21st of March to the 21st of June. For the south frigid zone the given day must be between the autumnal equinox and winter solstice, or between the 23d of September and 21st of December.

EXAMPLES.

1. In what latitude does the Sun begin to shine without setting on the 2d of June? *Ans.* Lat. 67° 49′ N.

2. In what latitude does the Sun begin to shine without setting on the 17th of October? *Ans.* Lat. 80° 47′ S.

In what latitude does the Sun begin to shine without setting on the following days?—

3. April 10.
4. June 21.
5. May 26.
6. October 18.
7. November 20.
8. December 1.

PROBLEM XXVII.

To find the latitude of those places in the frigid zone where the Sun does not set for a given number of days.

RULE.—Count as many degrees from the first point of Cancer, either way towards the equinoctial point, as is equal to half the number of days. Bring this point to the brass meridian, and observe the degree cut by it; subtract this from 90°, and the remainder will be the latitude required.

EXAMPLES.

1. In what latitude does the Sun shine continually for 60 days? *Ans.* 70° 10′.

2. In what latitude does he shine continually for 80 days?

3. In what latitude does he shine for one month?

4. In what latitude does he shine for 2 months? 3 months? 4 months? 5 months? 6 months?

PROBLEM XXVIII.

The day and hour at any place being given when a lunar eclipse will happen, to find all those places on the globe to which it will be visible.

RULE.—Find the Sun's place for the given time, elevate the pole which is most remote from the Sun as many degrees as his declination is north or south of the equator. Bring the given place to the brass meridian, and set the index to 12; then, if the given time be before noon, turn the globe *westward;* but if the

given time be after noon, turn the globe *eastward* as many hours as the time is before or after noon. The place exactly under the Sun's declination will be the antipodes of that place at which the Moon will be vertically eclipsed. Keep the globe in this position, and set the index to 12; turn the globe till the index has passed over 12 hours; then all those places above the horizon will have the eclipse visible. Those situated on the western edge of the horizon will see the Moon rise eclipsed, and those along the eastern edge will see her set eclipsed. Those places situated directly under the zenith, or that degree on the brass meridian 90° from the horizon, will see her vertically eclipsed.*

EXAMPLES.

1. An eclipse of the Moon commenced at Philadelphia on the 8th of March, 1849, at 6*h.* 20*m.* P. M., and ended at 9*h.* 20*m.* P. M.: where was it visible?

Ans. The Sun's declination being 4° 59′ S., the north pole should be elevated 4° 59′, and Philadelphia be brought to the meridian, and the index set to 12. The given time being 9*h.* 20*m.* after noon, the globe should be turned eastward till the index has passed over 9*h.* 20*m.* The index now should be set again to 12, and the globe be turned until the index has passed over 12 hours, when it will be seen that it rose eclipsed at Chicago, Louisville, Cincinnati, Mobile, Nashville, Natchez, and New Orleans, in the United States; the eastern shores of Yucatan, Nicaragua; and at Quito and Truxillo, in South America. It was vertical at the coast of Guinea, Liberia, and Sierra Leone, in Africa; and rose eclipsed in the middle of Siberia and Tartary, at Ava and Umerapoora, in Asia, and on the western shores of the island of Sumatra.

2. On the 20th of April, 1837, at 1*h.* 40*m.* P. M., mean time at Washington, the Moon was totally eclipsed: where was the eclipse visible, it having lasted 3*h.* 42*m.*?

Ans. It rose eclipsed at North Cape, Bergen, and Drontheim, in Norway; at London, Rochelle, Gibralter, and Sierra Leone. It was vertically eclipsed at a point in the Indian Ocean, in lon. 78° E., lat. 10° 39′ S.; and also to all places situated in that latitude, as far west as 22° E. lon. It set eclipsed at the Kurile Islands, Mulgrave Islands, Friendly Islands, and New Zealand. The eclipse was visible throughout almost all Europe, the whole of Asia, Africa, and Australia, but was invisible in North and South America.

* The Moon must be vertical to more than one place during her eclipse, for the Earth, being constantly rotating on her axis, brings new places in succession under the Moon during the time of her obscuration.

3. On the 27th of August, the moon was partially eclipsed, the beginning of the eclipse being at 3*h.* 59*m.* in the morning, and ending at 6*h.* 31*m.* A. M., mean time at Boston: where was it visible.

4. On the 10th of May, 1808, there was a total eclipse of the Moon, when it was 8 o'clock in the morning at Greenwich; where was it visible?

PROBLEM XXIX.

To illustrate the phenomenon of the Harvest Moon.

RULE.—*For North Latitude.* Elevate the north pole to the latitude of the place, moisten small pieces of paper and stick them on the ecliptic, 12° apart, beginning at the point Aries, and extending each way, until there are 12 or 13 pieces attached to the globe. Then turn the globe westward on its axis until the piece of paper nearest to the sign Pisces comes to the eastern part of the horizon, and set the index to 12. Turn the globe westward on its axis until the other pieces come to the horizon successively; the intervals of time shown by the index between the arrivals of the pieces to the horizon will show the difference of time between the Moon's rising every day.*

For the South Latitude.—Elevate the south pole to the latitude of the given place, mark the point Libra, and every 12° preceding and following that point. Bring that mark which is nearest to Virgo to the eastern edge of the horizon, and set the index to 12. Turn the globe westward until the other marks come to the horizon, and observe the hours passed over by the index, (or the hours must be observed on the equator;) the intervals of time between the successive appearance of the marks at the eastern horizon will be the difference of time between the Moon's rising.

The Harvest Moon in south latitudes is the full moon which happens about the vernal equinox; for as the seasons are the reverse from those in the northern hemisphere, the Harvest Moon in southern latitudes is in Virgo and Libra.

---

* The Sun is in Virgo and Libra in the autumnal months; the Moon is always full when she is in the opposite signs, which are Aries and Pisces, which consequently occurs in the autumn months. And although the Moon is in these signs twelve times in the year, it is only about the autumnal equinox that her orbit is nearly parallel with the horizon, so that there is very little difference in her rising for several nights.

In autumn, the signs Pisces and Aries being opposite to the Sun's place, they rise when the Sun sets; and as the Moon is in them when full, her rising is very remarkable.

CHAPTER II.

Problems on the Celestial Globe.

PROBLEM I.

To find the right ascension and declination of a star.

RULE.—Bring the star to the brass meridian; the degree of the meridian over the star is the declination, and the degree of the equinoctial under the meridian is the right ascension.

Right ascension may be expressed in degrees or hours, and the declination in degrees north or south of the equinoctial; or in north polar distance, which is the number of degrees from the North Pole, counting from 0° to 180°, which is the extremity of the South Pole.

In order to find the north polar distance, if the star be north declination, *subtract* the number of degrees which it is north of the equinoctial from 90°, and the *remainder* will be the north polar distance, or, which is the same thing, the distance from the North Pole: for example, the star α Tauri, or *Aldebaran*, is 16° 11′ declination. In order to find its north polar distance, we subtract 16° 11′ from 90°, which leaves 73° 49′, the north polar distance of Aldebaran. In like manner, if the star be south declination, *add* the number of degrees it is south of the equinoctial to 90°, and the *sum* will be the north polar distance. Thus, Sirius, or α Canis Major, is 16° 30′ south declination; therefore, 16° 30′, added to 90°, equals 106° 30′, which is the north polar distance of Sirius, or his distance from the North Pole.

EXAMPLES.

1. Required the right ascension in degrees and time, the declination, and north polar distance of *Wega*, or α Lyra.

Ans. R. A. 18*h.* 31*m.*, or 277° 45′; Dec. 38° 38′ N.; N. P. D. 51° 22′.

2. Required the R. A. in degrees and time, the Dec., and N. P. D. of *Rigel*, or β Orionis.

Ans. R. A. 5*h.* 7*m.*, or 75° 45′; Dec. 8° 23′ S.; N. P. D. 98° 23′.

3. *Algol*, or β Persei.
4. *Arcturus*, or α Boötis.
5. α Orionis, or *Betelgeuse.*
6. Canopus, or α *Argus.*

PROBLEM II.

The right ascension and declination, or right ascension and north polar distance, of a star being given, to find it on the globe.

RULE.—Bring the right ascension marked on the equinoctial to the brass meridian, then under the given declination marked on the meridian will be the star required.

EXAMPLES.

1. What is the name of that star whose right ascension is 20*h.* 9*m.* 10*s.* in time, or 302° 17′ 30″ in degrees, and 13° south declination, or 103° north polar distance? *Ans.* α Capricorni.

Required the stars whose right ascension and declination are as follows:

2.	R. A. 212° 0′.		Dec. 20° 0′ N.
3.	" 99° 30′.		" 16° 30′ S.
4.	" 29° 30′.		" 22° 42′ N.
5.	" 0*h*. 0*m*.	N. P. D.	31° 44′.
6.	" 15*h*. 56*m*.	"	109° 21′.
7.	" 1*h*. 0*m*.	"	1° 30′.

PROBLEM III.

To find the latitude and longitude of a given star.

Rule.—Bring that pole of the ecliptic which is in the same hemisphere with the given star to the brass meridian, and fix over it the quadrant of altitude. Hold the globe steady, move the quadrant till it comes over the given star; then the degree of the quadrant cut by the star is its latitude, and the degree on the ecliptic cut by the quadrant is its longitude.

EXAMPLES.

1. Required the latitude and longitude of *Aldebaran*, or α Tauri. *Ans.* Lat. 5° 28′ S., lon. ♊ 6° 53′.
2. Required the latitude and longitude of Pollux, or β Gemini. *Ans.* Lat. 6° 40′ N., lon. ♋ 20° 28′.
3. Regulus, or α Leonis.
4. Rastaben, or γ Draconis.
5. Fomalhaut, or α Pisces Australis.
6. Algol, or β Persei.

PROBLEM IV.

The day of the month being given, to find at what hour any star comes to the meridian.

Rule.—Bring the Sun's place to the meridian, and set the index to 12 o'clock. Turn the globe round till the given star comes to the meridian, and the index will show the hour.

If the star be east of the Sun, it will not come to the meridian till *after* the Sun; consequently it will be P. M. But if the star be west of the Sun, it will come to the meridian before him; and therefore the hour will be A. M.

EXAMPLES.

1. At what hour does Aldebaran come to the meridian on February 9? *Ans.* 6*h*. 55*m*. P. M.

At what hour do the following stars come to the meridian on Christmas-day?—

2. Sirius, or α Leonis.
3. Capella, or α Auriga.
4. Mizar, or ζ Ursa Majoris.
5. Canopus, or α Argus.
6. Procyon, or α Canis Minoris.
7. Caph, or β Cassiopeiæ.

At what hour will the following stars come to the meridian on the respective days?—

8. Regulus, or α Leonis, April 1.
9. Seginus, or γ Boötis, September 7.
10. Graffias, or β Scorpii, May 3.
11. Albireo, or β Cygni, August 1.
12. Phæt, or α Columba, October 10.
13. Scheat, or β Pegasi, August 31.

PROBLEM V.

To find on what day of the year any star passes the meridian at any given hour.

RULE.—Bring the given star to the meridian, and set the index to the given hour. Turn the globe till the index points to 12 at noon; the day of the month corresponding to the degree of the ecliptic under the meridian will be the day required.

EXAMPLES.

1. On what day does Spica Virginis come to the meridian at half-past nine in the evening? *Ans.* May 18.

On what days do the following stars come to the meridian at 10 in the evening?—

2. Algol, or β Persei.
3. Canopus, or α Argus.
4. Vindemiatrix, or ε Virginis.
5. Fomalhaut, or α Pisces Australis.
6. Kalpeny, or β Aquarii.
7. Wega, or α Lyræ.

On what days does Aldebaran come to the meridian at—

8. Noon?	10. 9 P. M.
9. 6 A. M.	11. Midnight.

On what days do the following stars come to the meridian at 3 A. M.?

12. Betelgeuse, or α Orionis.
13. Sirius, or α Canis Majoris.
14. Benetnasch, or η Ursa Majoris.

PROBLEM VI.

The latitude, hour, and day of the month being given, to find the altitude and azimuth of any star.

RULE.—Elevate the globe for the given latitude, bring the Sun's place to the meridian, and set the index to 12. Turn the globe till the index points to the given hour, screw the quadrant

of altitude on the zenith, and bring it over the star; then the degree upon the quadrant cut by the star will be its altitude, and the degree of the wooden horizon cut by the quadrant will be the azimuth.

EXAMPLES.

1. What is the altitude and azimuth of Sirius, or α Canis Majoris, at Washington, at 9 o'clock in the evening on Christmas-day? *Ans.* Alt. 17°, azimuth 51° E.

What are the altitude and azimuth of the following stars at Philadelphia, May 1, at midnight?—

2. Raselgeti, or α Herculis.
3. Wega, or α Lyræ.
4. Dubhe, or α Ursa Majoris.
5. Spica, or α Virginis.

What are the altitude and azimuth of the following stars at the Cape of Good Hope, June 1, at 9 in the evening?—

6. Spica, or α Virginis.
7. Acrux, or α Crucis.
8. Antares, or α Scorpii.
9. Agena, or β Centauri.

Required the altitude and azimuth of the following stars at Paris, October 5, at 10 in the evening?—

10. Alpheratz, or α Andromeda.
11. Mira, or o Ceti.
12. Mesartim, or γ Arietis.
13. Algol, or β Persei.

PROBLEM VII.

The azimuth of a star and the day of the month being given, to find the hour and the altitude of a star in a given latitude.

RULE.—Rectify the globe as in the last problem, screw the quadrant of altitude on the zenith, and bring it to the given azimuth. Turn the globe till the star comes to the quadrant; the index will then show the hour, and the altitude of the star will be shown by the quadrant.

EXAMPLES.

1. The azimuth of Antares, or α Scorpii, at Philadelphia, on the 21st of June, was S. 25° W.: required the altitude and hour of the night. *Ans.* Hour, midnight; alt. 20°.

Having found the azimuth of the following stars, required their altitude and their hour for London, on September 1.

2. Ras Alphague, or α Ophiuchi, S. 48° W.
3. Benetnasch, or η Ursa Majoris, N. 51° 30′ W.
4. Alphecca, or α Coronæ Borealis, S. 1° W.
5. Arcturus, or α Boötis, N. 81° W.
6. Mirach, or β Andromeda, N. 68° E.

PROBLEM VIII.

The altitude of a star, the day and the latitude being given, to find the hour and the azimuth.

RULE.—Rectify the globe as in the preceding problems, screw the quadrant of altitude upon the zenith, then turn the globe and move the quadrant till the star cuts the quadrant at the given altitude; the index will show the hour, and the quadrant the azimuth on the horizon.

As all the stars have the same altitude twice a day, it is necessary to state whether the star is east or west of the meridian.

EXAMPLES.

1. The altitude of Alderamin, (α Cephei,) at Alexandria, in Egypt, on the *morning* of August 9, was 41°: required the hour and the azimuth. *Ans.* Hour, 4 A. M.; azimuth, N. 34° W.

Having the altitudes of the following stars at New York, on the days given, required the time and the azimuth:

2. February, 15 P. M., Procyon, or α Canis Minoris; alt. 48° 30′.
3. December 25, P. M., Aldebaran, or α Tauri; alt. 30°.
4. July 4, A. M., Aldebaran; alt. 14° 30′.

Having the altitudes of the following stars at Quito, required the hour and azimuth:

5. May 12, A. M., Fomalhaut, or α Pisces Australis; alt. 34°.
6. June 30, P. M., Wega, or α Lyræ; alt. 24°.
7. December 19, A. M., Acrux, or α Crucis; alt. 21°.
8. March 3, A. M., Antares, or α Scorpii; alt. 36°.
9. January 1, P. M., Phæt, or α Columbæ; alt. 26° 30′.
10. October 10, P. M., Alpheratz, or α Andromedæ; alt. 62°.
11. September 5, A. M., Menkar, or α Ceti; alt. 70° 40′.

PROBLEM IX.

Having the azimuth of a star, the latitude and the hour, to find the star's altitude and the day of the month.

RULE.—Elevate the globe for the latitude of the place, screw the quadrant of altitude on the zenith, and bring it to the given azimuth; bring the star to the edge of the quadrant, and set the index to the given hour, and the degree of the quadrant cut by the star will be its altitude. Turn the globe till the index points to 12, and the day of the month marked on the ecliptic where it is cut by the brass meridian, is the day required.

EXAMPLES.

1. The azimuth of Arcturus at 6 P. M., at Philadelphia, was observed to be N. 80° W.: what was its altitude, and the day and month? *Ans.* Alt. 21°; October 15.

2. At Washington City, at 9 o'clock in the evening, the azimuth of Aldebaran was found to be S. 89° W.: required its altitude, and the day and month. *Ans.* Alt. 26°; March 21.

3. At the Cape of Good Hope, at midnight, the azimuth of Sirius was S. 83° W.: what was its altitude, and the day and month?

4. At Quito, at 10 o'clock, the azimuth of Achernar was S. 30° W.: required its altitude, and the day and month.

5. At Philadelphia, at 5 o'clock in the morning, the azimuth of *a* Arietis was S. 79° W.: what was its altitude, and the day and month?

6. At Rome, at 5 o'clock in the morning, the azimuth of Capella was observed to be N. 65° W.: required its altitude, and the day and month.

PROBLEM X.

The latitude and day of the month being given, to find the hour of the night by observing when two stars have the same azimuth.

Rule.—Elevate the pole to the given latitude, screw the quadrant of altitude on the zenith, bring the Sun's place in the ecliptic to the brass meridian, and set the index to 12; move the globe and the quadrant, till the quadrant comes over both stars; the hour will be shown by the index.

EXAMPLES.

1. At New York, on the 8th of February, the stars Betelgeuse and Rigel were observed to have the same azimuth: what was the hour? *Ans.* 10 o'clock, P. M.

2. At Jerusalem, on the 3d of September, the stars Almaac and Capella were observed to have the same azimuth: what was the hour? *Ans.* 2 o'clock A. M.

Required the hour at Nova Zembla, when the following stars have the same azimuth on the annexed days:

3. April 11, Etanin and Vega.
4. September 10, Capella and Betelgeuse.
5. March 31, Cor Caroli and Spica.
6. May 16, Arided and Enif.

PROBLEM XI.

To find the time of the rising, setting, and culminating of any star, for any given day and place.

Rule.—Elevate the pole for the given latitude, bring the Sun's place to the meridian, and set the index to 12. Turn the globe till the star comes to the eastern horizon, and the hour shown by

the index is the hour the star rises at that place on that day. Bring the star to the brass meridian, and the index will show the hour it culminates. Continue to turn the globe, and the moment the star comes to the western horizon is the time of its setting, as shown by the index.

EXAMPLES.

Required the time when the following stars rise, culminate, and set, at the respective places and days:

1. Spica, at Philadelphia, May 12.

Ans. Rises at 4*h.* 40*m.* P. M.; culminates at 10*h.* 0*m.* P. M.; sets at 3*h.* 25*m.* A. M.

2. Arcturus, at New Orleans, September 21.

Ans. Rises at 7*h.* 25*m.* A. M.; culminates at 2*h.* 15*m.* P. M.; sets at 10*h.* 10*m.* P. M.

3. Menkar, at Moscow, January 1.
4. Procyon, at Melville Island, June 21.
5. Alioth, at Demarara, December 19.
6. Achernar, at Potosi, July 4.

The degree of the equinoctial that rises with a star is its oblique ascension; the degree of the equinoctial that sets with a star is its oblique descension: the distance of a star from the east point of the horizon at its rising, is its eastern amplitude; the distance of a star from the west point of the horizon at its setting, is its western amplitude.

Required the oblique ascension, oblique descension, and eastern and western amplitude of the following stars, at the respective places and days:

7. Sirius, at London, on the 15th of March.

Ans. Oblique ascension, 120° 50′; oblique descension, 77° 15′; amplitude, 27° S.

8. Arcturus, at Queen Charlotte's Islands, March 10.
9. Betelgeuse, at Washington, October 1.
10. Aldebaran, at Cincinnati, September 30.

PROBLEM XII.

To show the appearance of the heavens for any given day and hour at any given place.

Rule.—Elevate the globe to the latitude of the place, bring the Sun's place to the meridian, set the index to 12, and turn the globe till the index points to the given hour. The constellations will be represented in their relative situations as they are in the heavens. By placing the end of a pencil on any star, the point of the pencil will indicate the direction of the same star in the heavens.

EXAMPLES.

1. Required the appearance of the heavens at Boston, on the 1st of January, at 9 in the evening.

Ans. Regulus and Cor Caroli are near the eastern horizon; Aldebaran is a little to the east of the meridian; Sirius and Procyon appear in the south-east; the constellation Orion is about two hours to the east of the meridian; Gemini is in the south-east; Ursa Major is in the north-east; Wega is just setting; Andromeda and Pegasus are west of the meridian; and Cetus and Aries are in the south-west.

2. Required the appearance of the heavens at Quito, September 20, at midnight.

3. What appearance do the heavens present at Cape Horn, at 4 o'clock A. M., May 31?

4. Describe the configuration of the heavens at Cairo, on the 10th of August, at 6 o'clock, P. M.

PROBLEM XIII.

To find what stars never rise or set at any place.

RULE.—Elevate the pole for the latitude of the place, and then hold a pencil at the north point of the horizon, and turn the globe round. The circle thus drawn will include, between it and the pole, all the stars which never set. Then hold the pencil at the south point of the horizon, and turn the globe; the stars included between the circumference of this circle and the depressed pole, never rise to that latitude.

By Calculation.

Find the co-latitude by subtracting the latitude of the place from 90°. If the declination of the star is greater than the co-latitude, and of the same name with it, it will never set; if it be greater than the co-latitude, and of a contrary name, it will never rise to that place.

EXAMPLES.

1. What stars never rise to those places in the same latitude as Boston? What stars never set to places in that latitude?

Ans. Those constellations which never rise are the greater part of Argo Navis, Equuleus Pictorius, Dorado, Reticulus, Horologium, Solarium, Hydrus, part of Phœnix, Toucana, part of Grus, Pavo, part of Telescopium, Octans, part of Norma, Circinus, Apus, Triangulum, part of Lupus, part of Centaurus, Crux, Musca Australis, Chameleon, Mons Mensæ, Pisces Volans, and Robur Caroli. Those stars which never sink below the horizon in that latitude are the constellation Cassiopeia, part of Perseus, Tarandus, Camelopardalus, part of Auriga, part of Lynx, the greater part of

Ursa Major, including the "Dipper," Quadrans Muralis, Draco, Cepheus, and Ursa Minor.

2. What stars never set at Calcutta?

Ans. All those situated between the Arctic Circle and the North Pole.

3. What stars never rise at Rio Janeiro?

Ans. Those which never set at Calcutta.

4. How far must a person travel south to lose sight of Capella?
5. How far south must a person travel to see α Centauri?
6. In what latitude is the star Sirius always below the horizon?
7. In what latitude is Sirius always above the horizon?
8. How far south do those live who never see Lyra?

PROBLEM XIV.

The latitude of the place being given, and the day of the month, to find what planets will be above the horizon after sunset.

RULE.—Elevate the pole for the latitude of the place, find the Sun's place in the ecliptic, and bring it to 10° or 12° below the western part of the horizon; then find the right ascension and declination of the planets for the given day in a good ephemeris or the Nautical Almanac, and those whose situations are above the horizon when the Sun is 10° or 12° below it in the west, will be visible either by the naked eye or a good telescope.

EXAMPLES.

1. What planets were visible at Philadelphia on the 1st of September, 1855, after sunset?

Ans. The right ascensions and declinations of the planets were, at that time, as follows:

	RIGHT ASCENSION.	DECLINATION.
Mercury,	11*h*. 2*m*.	7° 42′ N.
Venus,	12*h*. 42*m*.	10° 46′ S.
Mars,	8*h*. 10*m*.	21° 4′ N.
Jupiter,	21*h*. 55*m*.	13° 58′ S.
Saturn,	5*h*. 53*m*.	22° 14′ N.
Uranus,	3*h*. 14*m*.	17° 39′ N.
Neptune,	22*h*. 50*m*.	12° 0′ S.

Therefore, at sunset Venus was on the verge of the western horizon, Jupiter and Neptune were in the eastern horizon; the rest were at that hour invisible.

2. What planets were visible at Philadelphia on the 1st of September, 1855, at 4 o'clock, A. M.?

Ans. Jupiter and Neptune were setting; Mars had risen, and was an hour and a half high; Saturn was about midway between

the eastern horizon and the zenith; and Uranus was half an hour east of the meridian.

3. What stars will be visible at Boston, at midnight, on the first of next month of this year?*

4. What planets will be visible at Cairo, December 1, next, at 7 o'clock in the evening?

5. What planets will be visible at that place at midnight on that day?

PROBLEM XV.

To find on what day and hour a given star culminates.

RULE.—Bring the given star to the brass meridian, and set the index to 12; turn the globe westward till the index has passed over as many hours as the time is before noon; but if the given time be past noon, turn the globe eastward till the index has passed over as many hours as the time is past noon. Observe the degree of the ecliptic which is intersected by the graduated edge of the brass meridian, and the day of the month answering thereto will be the day required.

EXAMPLES.

1. On what day of what month does Spica come to the meridian at 10 minutes past 10 in the evening? *Ans.* May 10.

2. On what day of what month does Aldebaran culminate at midnight? *Ans.* December 1.

3. On what day of what month does Altair come to the meridian at 11 o'clock, P. M.?

4. On what day of what month does Benetnasch culminate at 2, A. M.?

5. On what day does Cor Caroli culminate at noon?

PROBLEM XVI.

To find the Sun's right ascension, oblique ascension, ascensional difference, eastern amplitude, and time of rising, at any given place on a given day.

RULE.—Elevate the pole for the latitude of the place, and bring the Sun's place to the meridian; the degree of the equinoctial cut by the graduated edge of the brass meridian is the Sun's right ascension. Set the index to 12, bring the Sun's place to the eastern edge of the horizon, and the degree of the equinoctial cut by the horizon is the Sun's oblique ascension. The difference between the right and oblique ascension is the

* The student must consult an ephemeris for the current year, in order to be enabled to solve this and the following question.

ascensional difference. The number of degrees on the horizon, between the Sun's place and the east point of the horizon, is the rising or eastern amplitude. The time shown by the index, when the Sun is in the horizon, is the time of his rising.

EXAMPLES.

1. Required the Sun's right ascension, oblique ascension, ascensional difference, eastern amplitude, and time of rising at Quebec, on the 5th of November.

Ans. Right ascension, 14*h.* 42*m.*; oblique ascension, 240°; ascensional difference, 20°; eastern amplitude, 23° 20′; Sun rises, 7*h.* 10*m.*

2. Required the Sun's right ascension, oblique ascension, ascensional difference, eastern amplitude, and time of rising, at St. Petersburg, on the 20th of May.

3. The same for Valparaiso, on the 1st of January.

4. The same for the Cape of Good Hope, on the 4th of July.

5. The same for the island of Juan Fernandez, on the 6th of October.

6. The same for North Cape, on the 15th of June.

PROBLEM XVII.

To find the Sun's oblique descension, descensional difference, western amplitude, and time of setting, for any place, on a given day.

RULE.—Proceed as in the last problem, only bring the Sun's place to the western horizon.

EXAMPLES.

1. Required the Sun's oblique descension, descensional difference, western amplitude, and time of setting, for the Cape of Good Hope, on the 19th of July.

Ans. Oblique descension, 103° 44′; descensional difference, 15°; western amplitude, 25° 30′; time of setting, 5*h.*

2. The same for Calcutta, on the 21st of June.

3. The same for San Francisco, on the 1st of January.

4. The same for Truxillo, on the 8th of May.

5. The same for Boston, on the 5th of February.

6. The same for New Orleans, on the 12th of November.

PROBLEM XVIII.

The latitude, day of the month, and hour being given, to find the Sun's altitude and azimuth.

RULE.—Elevate the globe for the given latitude, bring the Sun's place to the meridian, and set the index to 12; then turn

the globe till the index points to the given hour. Screw the quadrant of altitude on the zenith, and bring it over the Sun's place; the degree of the quadrant cut by the point of the ecliptic in which the Sun is situated, will be his altitude; and the distance between the graduated edge of the quadrant and the north and south points of the horizon, will be his azimuth.

EXAMPLES.

Required the Sun's altitude and azimuth at the following places and times:

1. Washington, May 18, 7*h.* 30*m.* A. M.
   Ans. Altitude, 30°; azimuth, N. 87° E.
2. St. Petersburg, December 21, 11*h.* 20*m.* A. M.
   Ans. Altitude, 6°; azimuth, S. 11° E.
3. Lima, August 31, 6*h.* 30*m.* P. M.
4. Bombay, April 1, 8*h.* 40*m.* A. M.
5. Lake Tchad, June 21, 7*h.* 0*m.* P. M.
6. Gottingen, March 10, 4*h.* 0*m.* P. M.

PROBLEM XIX.

To find the time of the Moon's southing, at any given place, at any given day.

RULE.—Find the Moon's place—that is, her right ascension and declination, or her longitude and latitude—by a good ephemeris or a nautical almanac, and mark her place on the globe by a little patch of paper moistened and stuck on it. Bring the Sun's place to the brass meridian, and set the index to 12; turn the globe westward until the Moon's place comes to the brass meridian, and the hours passed over by the index will show the hours from noon when the Moon will be on the meridian.

EXAMPLES.

1. On the 1st of November, 1855, the Moon's right ascension was 8*h.* 39*m.*, and her declination 23° 52′ N., at noon: at what hour on that day did she pass the meridian?

Ans. The Moon's time of southing was 18*h.* 30*m.* afternoon, or 6*h.* 30*m.* in the morning.

2. On the 1st of January, 1855, the Moon's right ascension was 5*h.* 16*m.*, and her declination was 25° 34′ N., at noon: at what hour did she pass the meridian on that day?

3. On the fifth of February, 1810, the Moon's R. A. was 10*h.* 44*m.* 36*s.*, and her Dec. 4° 48′ N.: what time did she pass the meridian?

4. On the 31st of December, 1811, the Moon's R. A. was 8*h.* 2*m.* 16*s.*, and her Dec. 17° 7′ N.: when did she pass the meridian?

PROBLEM XX.

To find when an eclipse of the Sun or Moon is likely to occur in any year.

RULE.—By the Nautical Almanac or a good ephemeris, find the places of the Moon's nodes for the given time; also, find the Sun's place for the given day; then find the Moon's place by the Nautical Almanac. If, at the time of full moon, (which happens when the Sun and Moon are directly opposite to each other, or 180° apart,) the Sun should be within 12° of the Moon's node, there will be an *eclipse of the Moon.* But if the Sun and Moon have nearly the same right ascension and declination, (which always happens at the time of new moon,) or if, at the time of new moon, the Sun be within 17° of the Moon's node, there will be an eclipse of the Sun.

EXAMPLES.

1. In 1855, on the 15th of May, the Sun's and Moon's right ascension was 3*h.* 29*m.*; the longitude of the Moon's node was 1*s.* 12° 9′; Moon's declination, 20° 5′ N.; and Sun's declination, 18° 56′ N.: was there an eclipse? and if so, was it of the Sun or Moon?

Ans. As the longitude of the Moon's node was 1*s.* 12° 9′ or 42° 22′, and the Sun's R. A. 3*h.* 29*m.* or 52° 15′, it follows that the Sun will be only 9° 53′ from the Moon's node; and as the Sun and Moon have the same right ascension, it must be new moon; therefore, there was an eclipse of the Sun.

2. On the 3d of January, 1855, there was full moon; the longitude of the Moon's node was 49° 28′; the Sun's right ascension 18*h.* 54*m.*; his declination 22° 51′ S.; the Moon's R. A. was 7*h.* 4*m.*, and her Dec. 26° 44′ N.: was there an eclipse of the Moon on that day?

Ans. There was not; for the Sun being more than 12° from the Moon's node, there could not be any eclipse.

3. There was full moon on the 26th of February, 1812, at which time the Moon's node was 158° 9′, and the Sun's longitude 337° 33′; was there an eclipse of the Moon at that time?

4. Was there an eclipse of the Sun on the 9th of November, 1855, when the right ascension of the Sun and Moon was 14*h.* 57*m.*, the longitude of the Moon's ascending node 32° 56′, the Dec. of the Moon 18° 8′ S., the Sun's Dec. 16° 47′ N.? and if so, was it an eclipse of the Sun or of the Moon?

5. On the 27th of March, 1812, there was full moon, at which time the place of the Moon's node was 5*s.* 6° 35′, and the Sun's longitude 7° 11′ 14″: was there an eclipse at that time? and if so, was it of the Sun or Moon?

History of Astronomy.

CHAPTER I.

SECTION I.

From the Earliest Times to the Christian Era.

"The only rational and just method of writing the history of a science, is to base it exclusively on works, the date of whose publication is *certain*. All beyond this must be confused and obscure."—Arago.

Astronomy is one of the most ancient of the physical sciences, having had its devotees from the earliest times to the present day. The greater part of its history having been lost in the lapse of ages, no *certain* conclusions can be gathered from the few shreds of truth which have come down to us, interwoven as they are with the falsehood and superstition of various nations. Yet, through the sagacity of those learned men who have investigated this subject, we are in possession of numerous facts which serve as landmarks whereby to direct our course through this labyrinth. Although we may meet with much error, there are many undeniable truths which merit the attention of the student, and serve to guide him in forming conclusions which are, after all, only an *approximation* to the truth; for, having no *certain* dates on which to rely, the early history of this science must necessarily be obscure.

The heavenly bodies first claimed the attention of man on account of an influence they were supposed to exert over the destinies of his race. A knowledge of the configurations of the heavens, and the art of predicting future events by the appearances of the stars, constituted a science called Astrology, which formerly engrossed the attention of the most learned.

It is to Astronomy we are indebted for our only accurate measures of time. The first period noted by man was no doubt counted by days or *suns*, then by months or *moons*, after which the apparent annual revolution of the Sun gave the idea of a *year*.

The various phases of the Moon and planets were supposed to foreshadow the events of human life; for which reason the appearances and movements of those bodies were anxiously watched, and often carefully recorded.

The Sun, possessing a benign influence on all animal and vegetable life, and being the fountain of light and heat, became an object of worship at a very early period.

ASTRONOMY OF THE INDIANS.

Our first accounts of the science of Astronomy are supposed to be derived from India: though the fact has never been proved beyond all doubt, still there is an accumulation of evidence in favor of its high antiquity and Indian origin. The Astronomy of India is considered more remote in its date than that of any other

nation. It undoubtedly presents a curious problem for the investigation of the learned, and one which is yet involved in great uncertainty.

It is undeniable that the Indian nations have more solid foundations than any others on which to rest their claims to precedency in this noble science. But whence did their knowledge originate? Was it communicated to them by a former race of men, of whom we are ignorant? We are in possession of Indian astronomical tables, and methods of computing the eclipses and places of the planets, forming altogether a treatise on Astronomy. Bailey and Professor Playfair imagined they could discern, in the computations and astronomical tables of the Indian nations, proofs of their having been made by a race who had derived their knowledge from some more ancient people.

There are several sets of Indian astronomical tables. The first ever known in Europe was introduced by La Loubère, an ambassador to India from the court of Louis XIV. A set of tables was brought from the Carnatic by Father du Champ, in 1750. Another was introduced about the same time by Patonillet, which is supposed to have come originally from Narsapour. A fourth set was brought by Le Gentil, a French astronomer, who had gone to India in order to witness the transit of Venus in 1769. These tables were communicated to Le Gentil by a learned Brahmin, and bear a date of much higher antiquity than any of the others. The epoch assumed by them is about the year 1300 B. C., and according to which the tropical year consists of but one minute, five seconds, and five-tenths more than the year according to Lacaille.

But this high antiquity claimed by the Brahmins is regarded by many of the learned as unworthy of credit; their calculations are suspected of having been extended back by means of more modern tables. La Place places the epoch of these tables at about the time of Ptolemy, or about A. D. 125, which date he proves to be nearly correct from the acceleration of the Moon.

Still, the phenomena are noted with so much accuracy as to leave little room to doubt that the observations were made by a people far advanced in the science. The only data, however, from which a rational conjecture can be formed relative to the antiquity of this science, are to be found in the existing monuments.

The Indian zodiac, which strongly resembles our own, is supposed by some to have been borrowed from the Greeks or Arabs; but Sir William Jones thought that it was probably invented by the progenitors of the Hindu race.

Admiral Smyth, of the Royal Navy, says—"The Hindu claim to antiquity stands on higher ground as a curious, but involved, historical problem. I cannot," he continues, "but be somewhat influenced by the learning and sagacity of Sir William Jones; the science and judgment of my friend, Mr. T. C. Colebrooke, late president of the Astronomical Society; the persevering spirit of inquiry of Mr Davis; and the talents of Schlegel." He further adds—"On the whole, we must allow that the early Hindus applied themselves intensely to the pure sciences, since they could compute the mean motions and true places of the planets, and calculate lunar and solar eclipses; they understood the astronomical sphere and its circles; suspected a libration of the equinoctial points; had a glimpse of geometry; were expert in instrumental observations; and enriched science with those powerful organs—arithmetic and algebra"

ASTRONOMY OF THE CHINESE.

The Chinese also claim the honor of having cultivated the science of Astronomy from a very early period; but, like the Hindus, their pretensions are disputed by some and sustained by others among the learned. The truth certainly rests in great obscurity, but there are facts which serve to prove an acquaintance with the heavenly bodies, as well as a certain degree of advancement in the methods of observation, the accuracy of which would imply some knowledge of instruments.

About 1100 years before the Christian era, certain astronomical observations were made in the city of Layang, in China, at the time of the summer and winter solstices. The obliquity of the ecliptic thus determined was 23° 54′ 3·15″. This determination of the position of the winter solstice corresponds with the calculations of La Place to within 1′ of arc. La Place considers this astonishing conformity as a certain proof of the authenticity of those observations.

The Chinese boast of a series of eclipses extending over a period of more than 3000 years, which, however, are not to be relied on, as they are supposed to have been computed back. They are only mentioned in the works of Confucius, the great Chinese philosopher, as *mere facts*, and are unaccompanied by any observations noted at the time.

The decimal divisions of time, of degrees of the circle, and of weights and measures, were in use among the Chinese 4000 years ago.

ASTRONOMY OF THE EGYPTIANS.

The Egyptians are generally supposed to have derived all their astronomical knowledge from the Oriental nations. They fixed the length of the year to 365¼ days, by observing the heliacal rising of the star Sirius, to which they gave the name of Thoth, (*watch-dog,*) because it immediately preceded the overflow of the Nile. This period of 365¼ days was their sacred year; their civil year consisted of only 365 days.

The difference between the lengths of the sacred and civil year led the Egyptians to the discovery of the sothic or canicular period of 1460 solar years, corresponding to 1461 civil years of 365 days, which brings back the months and festivals to the same seasons.

That the Egyptians were acquainted with some method of finding the true meridian line, seems to be proved by the fact that the pyramids are generally found to stand with their faces towards the four cardinal points. The builders of those monuments must also have been acquainted with the polar point of the heavens. It is an ascertained fact that many of the pyramids have narrow entrances, inclined at an angle equal to the altitude of what was then the pole star at its lower culmination.

Diodorus Siculus, who lived in the first century before Christ, informs us that the ancient Egyptians understood the phenomena of the stations and retrograde motions of the planets. Macrobius, a Latin historian, who flourished about the fifth century of the Christian era, ascribes to the Egyptians a knowledge of the real motions of Mercury and Venus, and says that they regarded these planets as satellites of the Sun.

Astronomy is also a useful aid in discovering the dates of ancient monuments. As an instance, on the ceiling of a portico among the ruins of Tentyris may be seen the twelve signs of the zodiac, placed according to the apparent motion of the Sun. According to this zodiac, the summer solstice is in Leo; from which it is easy to compute by the precession of the equinoxes of $50''\cdot 1$ annually, that the zodiac of Tentyris must have been made 4000 years ago. Mrs. Somerville relates that on one occasion she witnessed an instance of the successful application of Astronomy in ascertaining the date of a papyrus sent from Egypt. The manuscript was found in a mummy-case, and proved to be a horoscope of the time of Ptolemy. Its antiquity was determined by the configuration of the heavens at the time of its construction.

That portion or division of time consisting of seven days, and commonly known by the name of a *week*, has been used from the remotest times among the Indian nations, the Chinese, and Egyptians. It was also known to the Druids of Gaul and Britain, which seems an argument in favor of the common origin of the rudiments of this science. The division of a week was probably suggested by the phases of the Moon. Dion Cassius, a Greek historian, who lived about A. D. 250, says that the Egyptians were the first people who dedicated each day of the week to the Sun or one of the planets.

ASTRONOMY OF THE CHALDEANS.

The level country of Chaldea, with its fine, clear atmosphere, is peculiarly adapted to astronomical observations, which, according to some authors, extended over a period of more than 1900 years.

As the Chaldeans were shepherds, they would naturally be led to the contemplation of the heavens when engaged in tending their flocks; and as they were noted for their knowledge of the sister science, Astrology, they must have recorded the various changes continually occurring in the celestial bodies. Sir William Jones was of opinion that the practice of observing the stars originated with the rudiments of civil society, and in the country of the Chaldeans.

They were able to predict eclipses of the Moon by means of a cycle of 223 months, or about 18 years, at the end of which time the eclipses begin to return at the same intervals and in the same order. Delambre, who wrote a history of Astronomy, supposes that they carefully recorded all the eclipses which happened; and then, by inspecting their registers, they found the eclipses of the Moon to recur after a period of about 18 years. This period they called *Saros*, said to be a Chaldean word, signifying restitution or return. The Chaldeans had other cycles founded on the observations of the celestial bodies, which they termed *Sessos* and *Neros*, the meaning of which is now lost.

The following memoir appeared in the London Athenæum for January, 1855. It was sent by Colonel Rawlinson to the British Museum, the authorities of which communicated it to the Asiatic Society:—

Birs-i-Nimrûd is an immense shapeless mound, nearly 300 feet high, and from 200 to 400 feet in width where it reaches the plain. The whole mound is made up of crumbling rubbish, except the summit, which stands out like the fragment

of a watch-tower. It has, from time to time, excited the attention of tourists, several sketches of it having been drawn and afterwards published. The account given by Colonel Rawlinson is very graphic.

Having gained much experience in the mode of discovering ruins, he immediately ordered a perpendicular shaft to be sunk, at a designated point, until it should reach a wall. In the course of two months the workmen found the wall, which turned off at right angles at each end. Near the corner of this wall a small cavity was discovered, which contained a cylinder covered with inscriptions, which had remained during twenty-four centuries in its hiding-place.

The inscriptions were as fresh as when deposited there by the hands, probably, of Nebuchadnezzar himself! Another cylinder, a duplicate of the first, was found in another angle of the wall.

The inscriptions, like the deposits in the corner stones at the present day, give the name of the principal ruler, Nebuchadnezzar; and proceed with a summary of the buildings of Babylon, which the king had repaired or erected. It then mentions that the "*Temple of the Planets of the Seven Spheres,*" which had been built by an early king 504 years previously, or about 1100 B. C., having become ruinous, owing to a neglect of the drainage, the god Merodach had put it in his heart to restore it; that he did not rebuild the platform, which was unimpaired, but that all the rest was restored by his commands.

ASTRONOMY OF THE PHŒNICIANS.

The Phœnicians probably derived their astronomical knowledge from the Chaldeans and Egyptians. As they were the greatest navigators of ancient times, it is to be supposed they must have made some observations of the heavenly bodies, in order to perform even their short voyages to the islands of the Mediterranean, and the coasts of Spain and Africa.

ASTRONOMY OF THE GREEKS.

We are indebted to the Greeks for a more perfect knowledge of Astronomy than is to be derived from the writings of any other nation; for the works of many of their poets and philosophers have come down to us entire. Hesiod, a Greek poet, designates the various seasons by the "*turning of the Sun.*" Thus, he says—"Fifty days after the turning of the Sun is the favorable time to begin a voyage." Hence, we may infer that the ancient Greeks divided their year by the recurrence of the solstices.

The motions of the Moon, as well as the apparent motions of the Sun, were known to the Egyptians, Indians, Chaldeans, Phœnicians, and most probably to the Chinese, before they were observed by the Greeks. Thales, a Phœnician by birth, but a citizen of Miletus, is considered as the first person who propagated any truly scientific knowledge of Astronomy. It is supposed that he acquired some of his learning in his own country and in Crete. He was taught Geometry, Astronomy, and Philosophy, under the priests of Memphis.

Anaximander, an Ionian philosopher, and disciple and successor of Thales, lived about 500 B. C. He is said to have pronounced the Earth a sphere, and to have

had some idea of its revolution on its axis. He is supposed to have observed the obliquity of the ecliptic. He maintained that in the universe there is an infinity of worlds, and that the Moon shines by light of the Sun reflected from her surface.

Pythagoras, who flouished about 500 B. C., is said to have discovered the morning and evening star to be one and the same body. He taught that the Sun is fixed in the centre of the system, and that the Earth, with the other planets, revolves round the Sun; that the planets are inhabited; that the comets are material bodies, which revolve round the Sun at stated periods; that the fixed stars are suns, shedding light and heat around them. Pythagoras made a geometrical discovery with regard to the properties of the right-angled triangle, showing that the science of Geometry also engaged a portion of his attention.

The system of the universe, as taught by Pythagoras, although it has since been found to be a very near approximation to the truth, was for a time superseded by the theories of later philosophers.

The followers of Pythagoras conceived a comet to be a planetary body, which reappears after a certain interval, and which approaches as near the Sun as the planet Mercury when at the vertex of the curve it describes. Thus, it appears the Pythagorean philosophy, in some respects, strongly coincides with that taught at the present day.

Anaxagoras, who was a cotemporary of Pythagoras, taught that the heavens consisted of a solid vault of stones, elevated above the Earth by the surrounding ether, and that the Sun is a huge fiery stone, about the size of the Morea, a peninsula of Greece. For this theory he suffered banishment, it being considered impious thus to rob the Sun of his divinity, he being believed to be Apollo, one of the most powerful deities. According to Cicero, Anaxagoras was the first who taught the existence of a Supreme Intelligence, the Creator of all things.

About 430 B. C., Meton, an Athenian mathematician, constructed the luni-solar cycle, consisting of 6940 days, or about 19 years, now called the *Metonic Cycle*, in honor of its discoverer. It was inscribed in letters of gold on a marble pillar, for which reason the number indicating the order of the current year in that cycle is still called the *Golden Number*. The Metonic cycle was adopted on the 16th of July, B. C. 433.

Democritus, a celebrated philosopher, lived about 400 B. C. He travelled into Egypt, Chaldea, and India, by which means he spent a large fortune, and returned to his own country poor in purse, but rich in knowledge. All his works are lost; but, according to the testimony of others, he was a great philosopher. He taught that the light of the Milky Way is caused by a countless number of stars crowded together, and that other planets would be discovered to belong to our system.

Eudoxus, who lived B. C. 350, was distinguished for his knowledge of Astronomy, which it is said he acquired in Egypt, where he spent thirteen years in study under the priests. He was the author of some scientific works, which have been partially preserved in the writings of others of his countrymen. He built an observatory at Cnidus, which Strabo speaks of as partly in ruins in his time.

Pytheas, who lived about 380 B. C., was a celebrated astronomer of Marseilles, or, as it was then termed, *Massilia*. He travelled as far north as the northern part of Norway, or perhaps Iceland, and discovered the great diminution of the

lengths of the nights at the summer solstice. His accounts were at first deemed fabulous, but modern astronomers consider him as the first person who taught us to distinguish climates by the difference in the length of the days and nights.

In about a century after Meton discovered the cycle of 19 years, Calippus found that in order to make allowance for the hours by which 6940 days are greater than 19 years, a day should be left out at the end of 76 years, or four Metonic cycles. This is called the *Calippic period*, and is an improvement on the cycle of Meton.

Timocharus and Aristillus, who flourished about 300 B. C., made many important astronomical observations. They observed and recorded the relative positions of the fixed stars, the places of the planets, and the times of the solstices, during a period of at least 25 years.

The first person who attempted to measure the relative distances of the Sun and Moon was Aristarchus, of Samos. He also taught the stability of the Sun and the revolution of the Earth, for which he was accused of impiety.

Appolonius, of Perga, in order to account for the motions of the heavenly bodies, is said to have introduced the complicated system of *epicycles* into the Grecian astronomy. These epicycles were imaginary revolving circles, having their centre within a larger circle, which in their rotations were supposed to carry the planets with them. Although this theory of Appolonius is now exploded, yet it could not have been formed without considerable knowledge of the movements of the planetary bodies.

Posidonius estimated the distances of the Sun and Moon from the Earth: that of the Sun to be five hundred million stadia, and that of the Moon two million stadia. The atmosphere he computed to be four hundred stadia in height, which is not very far from the present estimate.

Eratosthenes, a native of Cyrene, and second librarian of the Alexandrian Library, lived about 200 years before the Christian era. He observed the obliquity of the ecliptic by means of the shadow of a style at Alexandria. He made use of two *armils*—instruments formed of brass circles—which were placed in the portico of the Square Porch at Alexandria, and were long used for the purpose of observations of the Sun, &c.

At the city of Syene, situated in Ethiopia, under the Tropic of Cancer, was a well, the bottom of which was said to have been illuminated on the day of the summer solstice. Eratosthenes supposed the cities of Alexandria and Syene to be on the same meridian, and by certain measurements by means of a style or gnomon, he computed the distance between the two cities to be one-fiftieth part of the circumference of the whole Earth. According to Noriet, a French astronomer under Napoleon, the measurement of Eratosthenes is too small by twelve minutes.

But the most indefatigable of the ancient astronomers was Hipparchus, who lived 150 years before the birth of Christ. He discovered the precession of the equinoxes, or very slow apparent motion of the fixed stars from east to west. He made this discovery by comparing the observations of Timocharus and Aristillus, made about 150 years before, with his own. He was the inventor of many astronomical instruments, by means of which he noted the apparent magnitudes and

places of the heavenly bodies. He also rectified the length of the tropical year of 365 days 6 hours, to within less than 5 minutes of the truth, as found by modern observers. Having observed a star which he thought was a stranger to him, he resolved to make a catalogue of all which were visible, so that if any changes should take place in the configurations of the heavens, future generations might be able to detect them. His catalogue consisted of more than 1000 stars, which he traced on an artificial globe, and which was afterwards placed in the Alexandrian Library. Delambre says Hipparchus appears to be the author of every great step in ancient astronomy.

From the time of Hipparchus until the Christian era, the science of Astronomy was but little cultivated.

Julius Cæsar, who was born 100 B. C., was a benefactor to the science by remodelling the calendar. He was well acquainted with Astronomy, and invited Sosigenes, an Egyptian mathematician and astronomer, to assist him in his labors. They fixed the length of the year to 365 days 6 hours. This is called the Julian Year.

SECTION II.

The Astronomical Instruments of the Ancients, from the Earliest Times to the Christian Era.

That the ancients made some tolerably accurate observations on the situations, magnitudes, and movements of the heavenly bodies, appears certain from the astronomical tables and other works which have come down to us.

Perhaps the altitude of the Sun was the earliest measurement of angular distance. This was determined by means of a gnomon, the invention of which is attributed to the Babylonians by Herodotus; but it was also used by the Indians, Chinese, and Egyptians.

This instrument consisted of a perpendicular staff or pillar, situated in a place exposed to the Sun, so that the shadow of the staff might be measured at various times during the year; the difference of the length of the shadow served to determine the *altitude* of the Sun.

The gnomon was used by the Greeks at a very early period. It was sometimes made with a small hole in the top, to permit the rays of the Sun to pass through, and by that means to determine more accurately the length of the shadow. It is also supposed that the ancient Egyptians, and other Eastern nations, used this instrument to find the cardinal points. It is inferred that the pyramids and pagodas were placed due east and west by means of the gnomon.

Thales erected a gnomon at Sparta, and set up the first sun-dial at Lacedæmon, by means of which he discovered the times of the equinoxes and solstices.

In 1467, a gnomon was erected at Florence, by Toscanelli, which was 277 feet high. Another, 80 feet in height, was formerly erected in Paris.

A very ancient instrument for measuring angles was the hemisphere of Borosus. It consisted of a hollow hemisphere with a horizontal rim, with a style placed in such a manner that the extremity of the style was in the centre of the sphere. The shadow of the style indicated the altitude of the Sun. This instrument served

rather for dividing the day into equal portions of time, than for determining positions.

Instruments composed of circles were used for measuring angles. They had a border or limb, which was divided into equal parts, and these again subdivided.

About the year 200 B. C., Ptolemy Euergetes caused two armils (*armillæ*) to be erected in the portico at Alexandria. These instruments consisted of a circular thin plate of metal, so placed that the edge should coincide with the direction of the equator. Therefore, the Sun would shine *under* the plate when he was *south* of the equator, and *over* the plate when he was *north* of it. The moment when his rays would fall directly on the thin edge, and neither above nor below it, would designate the time of the equinox. This instrument was called an equinoctial armil. Observations taken in this manner must necessarily be very inaccurate, owing to the refraction.

The armil was graduated into 360°, and each degree into six parts of 10′ each.

Ptolemy Claudius describes the *solstitial* armil as consisting of two concentric rings, one sliding within the other. The inner one was furnished with two pegs, exactly opposite to each other. These circles were fixed in the plane of the meridian, and the inner one turned till the shadow of one peg would fall exactly upon the other. The position of the Sun at noon would be determined by the degrees on the outer circle. The angles measured by these instruments would be expressed by parts of the whole circumference of a circle.

It was soon found to be unnecessary to use the entire circumference of the circle for the purpose of making angular observations. Ptolemy employed an instrument somewhat resembling the mural quadrant of modern times. A quarter of a circle was described on a piece of wood or stone, which was divided into degrees and parts of a degree. This instrument was placed in the direction of the meridian, and in the centre of the arch a cylinder of wood was fixed perpendicular to the plane of the instrument, so as to project its shadow upon the limb of the quadrant, thus designating the altitude of the Sun or Moon. At the extremity of the radius, below the cylinder, was another cylinder fixed in a vertical position, which is supposed to have been used with the plumb-line to adjust the instrument to the horizon. Theon, a celebrated mathematician, states that a horizontal position was given to the quadrant by means of a water-level.

The *dioptra* was an instrument invented by Archimedes, and improved by Hipparchus. It consisted of two rulers, each seven feet long, and movable round a common centre. A sight was fixed at the centre of motion, and one at the extremity of each rule. The diameter of the Sun or Moon was then comprehended between the two sights, and the opening of the rulers, or the angles which they formed, was the measure of the diameter of the luminary.

The Egyptians measured the angular diameter of the Sun or Moon in the following manner:—They observed the direction of the shadow of the gnomon of an equinoctial dial on the day of the equinox, at the moment the upper edge of the Sun appeared above the horizon; and again, its direction when the lower edge became visible. The angle between these lines is that subtended by the diameter of the Sun. This method is liable to great error, for the Egyptians estimated the true diameter of the Sun three times greater than the truth.

They measured the angular diameter of the Sun much more accurately by means of the *clepsydra*. It consisted of a vessel with several small openings at the bottom, through which the water contained in it was permitted to escape. The clepsydra was probably invented in Egypt under the Ptolemys, though some authors ascribe the invention to the Greeks, and others to the Romans.

These instruments were employed in the following manner:—They measured the quantity of water which flowed during the rising of the Sun's disc on the day of the equinox, and compared it with the quantity which flowed during the whole day; the proportion of the latter to the former was considered the same as that of the circumference of a circle to the arc which subtends the angular diameter of the Sun. By this method they obtained the angular measurement with tolerable exactness, considering the means employed to arrive at it.

A most singular method for measuring the angular diameter of the Sun was proposed by Cleomedes. The moment the upper limb of the Sun was seen to appear above the horizon, a horse was set off in a gallop on a plain; and the moment the whole disc became visible, he was to be stopped. The distance run by the horse was found to be ten stadia; and if the motion of the Earth were equal to that of the horse, he concluded the diameter of the Sun would be equal to ten stadia. This method is singularly absurd.

CHAPTER II.

SECTION I.

From the Christian Era to the year Sixteen Hundred.

Ptolemy, who flourished during the first half of the second century of our era, is noted for his *Megale Syntaxis*, or, as it was afterwards called, the *Almagest*. This work contains the principal discoveries of Hipparchus, and his catalogue of stars, which has been already noticed. This catalogue Ptolemy reduced to his own time, either by observation or by corrections for the precession of the equinoxes, a discovery of Hipparchus which he confirmed.

The theory of the system as taught by Ptolemy was, that the Earth is placed in the centre of the universe, and that the Sun, Moon, and planets move uniformly in circles, the centres of which circles move in regular circles round the Earth. The origin of this theory, says Grant, belongs to a "much higher antiquity."

The order of the planets, according to the Ptolemaic theory, is, the Earth in the centre, next the Moon, Mercury, Venus, the Sun, Mars, Jupiter, and Saturn.

The discovery of refraction is said to be due to Ptolemy, who made some rude experiments to explain its law, which were partially successful. He also explained the difference in the apparent magnitudes of the Sun and Moon when near the horizon.

Another great discovery was made by Ptolemy, namely: the evection or second inequality in the Moon's motion. He also applied himself to the study of music, geography, and chronology; and was, according to some, a believer in the science of astrology, which was studied by most of the ancients. Other authors deny

that Ptolemy lent his sanction to astrology, it never having gained admittance into his penetrating mind. The former opinion, however, is generally entertained.

As Ptolemy was desirous of transmitting his herculean labors to posterity, he caused his systems of the universe to be engraven on stone and erected in the Temple of Serapis, at Canopus, according to the authority of Theodorus.

Hypatia, the daughter of Theon II. of Alexandria, wrote one book of a commentary on the Almagest, the remaining part of which was written by her father. She was among the first female scientific writers. Among her works are some mathematical tables of her own construction. Her reputation for learning, and her purity of life, created a jealousy in the minds of some; and in the year 415, she was assassinated by a mob in the streets of Alexandria.

ASTRONOMY OF THE ARABIANS.

From the time of Ptolemy, a period of 600 years elapsed without any advances having been made in this science.

During an interval of about 1300 years, astronomical science was entirely in the possession of the Arabians, who received it from the Greeks. The Arabian astronomers made inconsiderable additions to those thus obtained; some of them, however, have been handed down, and are in use at the present day. Instead of the sexagesimal arithmetic of the Greeks, the Arabs introduced the notation by means of digits, 1, 2, 3, &c., which in fact are of Indian origin. They also introduced some important mathematical inventions.

The first Arabian astronomer of note was the Caliph Almansor, who reigned A. D. 754. He not only encouraged, but cultivated the sciences. His grandson, the great Harun-al-Raschid, began to reign in the year 786. Like his grandfather, he cultivated the sciences, especially Astronomy. In 799 he sent to Charlemagne a clepsydra, or water-clock, of very ingenious construction. "In the dial were twelve small doors, forming the divisions of the hours; one of these doors opened at each successive hour and let out little balls, which, falling on a brazen bell, struck the hour. The doors continued open till twelve o'clock, when twelve little knights, mounted on horseback, came out together, paraded round the dial, and shut all the doors."

Almamon, the son of Harun-al-Raschid, reigned at Babylon in 814. He studied the sciences from a Christian physician, named Musva, and used every means to inspire a love of learning in his subjects. He caused all the best writings of the Greeks, and in particular Ptolemy's Almagest, to be translated into Arabic.

Almamon determined the obliquity of the ecliptic to be 23° 35′, or, according to Vossius, 23° 34′.

During the reign of the Caliph Almamon, lived Albategnius, surnamed the Arabian Ptolemy, who made many valuable observations in Mesopotamia about the year 880. He wrote a work entitled *De Scientia Stellarum*, which included all then known in the science of Astronomy. It was afterwards translated into Latin.

Ebn-Junis, who lived about the year 1000, was astronomer of Akim, the caliph of Egypt. He made observations at Cairo, proving that the mean motion of the Moon is subject to a small acceleration, which, accumulating after a long lapse

of time, must be admitted into astronomical calculations. He was the author of a set of tables which were long in use in the East.

When the Arabs were settled in Spain, they built observatories in several cities, and paid great attention to the cultivation of Astronomy.

In 1020, Arzachel distinguished himself by his researches and observations. He made a set of astronomical tables, entitled Tabulæ Toledanæ.

In 1100, Alhazen, another Arabian astronomer, settled in Spain. He wrote a work on Optics, in which he explains the true cause of refraction and twilight. He also invented two theorems in spherical trigonometry, which are of great use in Astronomy.

ASTRONOMY OF THE PERSIANS.

The Persians, from the fifth century before the Christian era, were zealous observers of the heavenly bodies, in which they were encouraged by the example of many of their emperors.

They devoted themselves to determining the length of the year, which they fixed to 365 days and 6 hours. But they did not count the 6 hours in every year, but made it to consist just of 365 days. In order to account for the 6 hours, they intercalated a month of 30 days in every 120 years, which is the same as intercalating one day in every 4 years, according to the Julian method. As this was found to exceed the period of the Earth's revolution by about eleven minutes, Omar Cheyham, a Persian astronomer, undertook to rectify this error. He proposed to add a day every fourth year for seven periods of four years each, and then a day to the fifth year for the eighth period, and so on. This system, which is very near the truth, was adopted instead of the intercalary month above mentioned, and has been retained in Persia to the present time.

ASTRONOMY OF THE TARTARS.

Genghis Khan, the founder of the Mogul Empire, was very fond of all the sciences, especially Astronomy, to the professors of which he showed the highest respect. Houlagou Khan, one of his descendants, about the year 1264 built an observatory in the city of Maragha, and invited a great number of astronomers to dwell there. He appointed Nassir Eddin as president of their society, and encouraged every advancement in the study of Astronomy. Nassir Eddin wrote several works, among which are a Treatise on the Astrolabe, the Motions of the Heavenly Bodies, and some astronomical tables.

About the year 1450, lived Ulugh Begh, grandson of Tamerlane, and prince of the Tartars, who was one of the most learned men of his age. He established an astronomical academy in Samarcand, the capital of his dominions, and furnished it with the best instruments which could be procured.

Some of the works of Ulugh Begh are now in print, and some are in manuscript, in a few libraries. His best work is his Catalogue of the Stars and Astronomical Tables, which were the most perfect then known in the East.

After the death of this prince, Astronomy was not studied to any extent in the East, and finally became so interwoven with Astrology as to be no longer identified. The Persians of the present day have but a meagre knowledge of the science.

ASTRONOMY OF MODERN EUROPE.

The Arabians preserved the knowledge of Astronomy, which they had derived chiefly from the Greeks, and in the practical department of the science displayed a striking superiority to their masters.

In the ninth and tenth centuries, men of learning travelled into Spain for the purpose of studying Astronomy and Mathematics at the Moorish universities. About the year 1250, Alphonso X., King of Castile and Leon, founded at his capital a college for the advancement of Astronomy. He caused a new set of astronomical tables to be published, which were known as the *Alphonsine Tables.* They were executed at an immense expense, under the superintendence of some of the most learned astronomers of that day, both Arab and Jewish. About this time Frederic II., Emperor of Germany, caused the works of Aristotle and Ptolemy to be translated into Latin.

Roger Bacon, one of the most extraordinary minds of that or any age, made some valuable suggestions in the construction and use of astronomical instruments. He also proposed a reformation in the calendar three hundred years before any corrections were made in it.

Nicholas Copernicus, who was born at Thorn, in Prussia, in the year 1473, is known as the restorer of the true system of Astronomy. Being gifted with rare sagacity, he soon learned to distinguish the simple operations of nature from the intricate theories invented by man.

About the year 1507, Copernicus became a convert to the system of Astronomy embraced by Pythagoras, but which had its origin at a period prior to the time of the latter philosopher. According to the theory of Copernicus, the planets move in circular orbits from west to east, in the following order—viz. Mercury, Venus, Earth, Mars, Jupiter, and Saturn; the Moon revolves round the Earth, and also accompanies the latter body round the Sun.

Although he believed the orbits of the planets to be circular, he did not conceive them to be concentric. The Sun's place, according to his theory, was not in the common centre, but a position so placed with regard to them all as with the addition of some epicycles might account for all the observed phenomena. He was led to renounce the theory of the Earth in the centre of the system, because all the exterior planets presented such variable appearances in the different parts of their orbits. He especially observed the variable brilliancy of Mars and Jupiter; for when the former is in opposition to the Sun, he almost rivals Jupiter in brilliancy, while near conjunction he was no brighter than a star of the second magnitude. This fact led him to conceive the idea that the superior planets revolve around the Sun instead of around the Earth.

The phenomena of the interior planets he found clearly explained in the Egyptian Astronomy, which ascribes to the planets Mercury and Venus orbits having the Sun for a centre. This theory, Copernicus found, would account for the apparent oscillation of those planets on each side of the Sun.

Some of the ancient philosophers had supposed the fixed stars to be at rest, and explained their apparent diurnal motion from east to west by ascribing to the Earth a revolution on its axis in the contrary direction; that is, from west to

east. Copernicus embraced this doctrine of the Earth's rotation, and thus combined all these fragments of truth into a system which accounted more clearly than any of its predecessors for the phenomena observed in the motions of the heavenly bodies.

The doctrine that the Earth is the centre of the system, so strenuously maintained during the 1400 years which elapsed from the time of Ptolemy, was completely refuted by Copernicus, who revived the true theory of planetary motions; yet it must be understood that the system he promulgated, and which is distinguished by his name, is not strictly that which is known as the true planetary system at the present day. In 1543, Copernicus published his work, "*De Revolutionibus Orbium Cœlestium*," explaining the solar system, with the Sun in the centre. He lived only a few hours after he received the first copy.

After the death of Copernicus, the science of Astronomy received a fresh impulse from the researches of Nonius, Appian, the Landgrave of Hesse, and many others. Nonius was the inventor of some astronomical instruments, among which is an improvement on the divisions of the limb of the quadrant then in use. He also made many valuable discoveries in the sciences of mathematics and navigation.

About 1560, William IV., Landgrave of Hesse-Cassel, built an observatory in his capital, and furnished it with the best instruments of that day. He made many observations on the fixed stars, a catalogue of which was formed by Snellius. His catalogue consisted of 400 stars.

Contemporary with the Landgrave of Hesse, and in close intimacy with him, lived Tycho Brahé, one of the greatest observers that ever lived. He was born in Denmark, in the year 1546. He would not acknowledge the truth of the Copernican system, though it must have been evident to a mind like his, that it was more in accordance with the observations of the planetary motions than any other then known. Yet, although Tycho could not embrace the theory of Ptolemy, his superstitious feelings would not permit him to endorse the doctrines of Copernicus. He therefore adopted a system of his own, which was, that the Earth is immovably fixed in the centre of the system, about which first revolved the Moon, and then the Sun, which carried with it in its sphere of rotation the planets Mercury, Venus, Mars, Jupiter, and Saturn. This is known as the Tychonic system.

Tycho Brahé constructed some astronomical instruments on a much larger scale than were ever made before; by means of which he applied himself diligently to celestial observations. He discovered the variation of the Moon, and determined the inclination of the lunar orbit with more precision than had ever been done before.

Tycho denounced the then prevalent theory that comets were only transient meteors, and demonstrated them to be solid bodies, revolving round the Sun at stated periods.

In the year 1572, he observed a new star in the constellation Cassiopeia, which induced him to make a new catalogue of stars. He built an observatory on the island of Huen, under the patronage of Frederick II., King of Denmark, which he called Uranibourg, or the *City of the Heavens*.

The next noted astronomer which appeared was Galileo, who was born at Pisa,

in 1564. While yet a student at the university, he was one day in the cathedral at Pisa, and, perceiving a lamp which was suspended from the ceiling swinging to and fro, he was impressed with the idea that the lapse of time might be measured by a pendulum.

During the latter end of this century, Galileo made many experiments on the velocity of falling bodies, which, being opposed to the popular theories as taught by the followers of Aristotle, required no ordinary degree of sagacity to overthrow; for they were so thoroughly interwoven with many of the other doctrines of that great philosopher, as to render it at once difficult and unpopular to attempt to destroy that which had apparently stood the test of ages. The strongest prejudices were roused against him, so that in 1592 he quitted Pisa, though not before clearly proving the truth of his own theories by actual experiments made from the Leaning Tower of that city.

About the year 1600, he succeeded in constructing a telescope, with which he discovered the satellites of Jupiter, inequalities in the surface of the Moon, innumerable fixed stars, and a ring, or as he then described it, *handles*, (ansæ,) to the planet Saturn. These discoveries he announced in the *Sidereal Messenger*, which was published in Venice in 1610.

While Galileo was pursuing his discoveries in Italy, a star arose in Germany whose light was destined to shine throughout all future ages. This was John Kepler, who was born at Wittemburg, in Germany, in 1571. He adopted the theory of Copernicus, and discovered the cause of the tides in the ocean. His great work is *De Motibus Stellæ Martis*, in which he proves that Mars moves in an elliptical orbit, in one of the foci of which the Sun is placed. Upon this discovery he established his first and second laws of planetary motion—viz. 1. All the planets move in ellipses, having the Sun in one of the foci; 2. A line drawn from a planet to the Sun sweeps over equal areas in equal times. He discovered the fourth inequality, or annual equation of the Moon; he also supposed the existence of a planet between the orbits of Mars and Jupiter, too small to be visible to the naked eye, and that the Sun has a revolution on its axis; which facts have been since proved.

Descartes, born in 1596, at Touraine, was one of the greatest geniuses of the seventeenth century, although, perhaps, his labors did not promote the progress of Astronomy to as great a degree as some of his contemporaries whose minds were less liberally endowed. His hypothesis of *ethereal vortices* is considered by some to have paved the way for the mechanical theory of planetary motions; but Delambre has justly remarked that, by misleading men's minds from nature, this fiction of the imagination retarded, rather than promoted, the progress of true science. Descartes made important discoveries in mathematical science, and did much to overthrow the Aristotelian philosophy.

About the same period, and contemporary with Descartes, flourished Huyghens, a philosopher gifted with equal genius, but possessing greater discrimination and caution. He is distinguished for his telescopic observations, among which are his discovery that the appendage with which Saturn is furnished is a luminous ring, and also detected the most conspicuous satellites of that planet.

SECTION II.

Astronomical Instruments Invented from the Christian Era to the year Sixteen Hundred.

We have but little handed down to us with regard to the *means* used by the ancients to determine the various phenomena, some of which are so accurately recorded. All we know of their astronomical instruments is, that they were much less accurate than those of our day.

About the year 1830, when Sir John Malcolm, formerly governor of Bombay, visited Maragha, in Persia, he traced distinctly the foundations of the observatory constructed in the 13th century for Naser-ood-Deen, the favorite philosopher of the Tartar prince *Hoolakoo*, or *Hulagou*, the grandson of Genghis Khan, who, in this locality, relaxed from his warlike toils, and assembled around him the most learned men of the age; who, having commemorated his love of science, have given him more fame as its munificent patron, than he acquired by all his conquests.

In this observatory, according to one of the best Mohammedan writers, there was a species of apparatus to represent the celestial sphere, the signs of the zodiac, and the conjunctions, transits, and revolutions of the heavenly bodies. Through a perforation in the dome, the rays of the Sun were admitted so as to strike upon certain lines on the pavement, indicating in degrees and minutes the altitude and declination of that luminary during every season, and to mark the hour of the day throughout the year. The observatory was further supplied with a map of all the known parts of the terrestrial globe, as well as a general outline of the ocean, with all the islands then discovered. According to a Mohammedan author, all these were so arranged and delineated as "to remove, by the clearest demonstration, every doubt in the mind of the student."

There is a story extant, though of doubtful authenticity, that Ulugh Begh caused an enormous quadrant, of 180 feet radius, to be constructed, with which he made observations. The management of such an unwieldy instrument seems physically impossible. Certain it is, however, that those astronomers found the latitude of Samarcand, and fixed the obliquity of the ecliptic to but a fraction more than two minutes from that found by modern observers.

Towards the end of the thirteenth century, Wallingford, Abbot of St. Albans, made a clock for his convent, which indicated the hours, the courses of the Sun and Moon, the time of high water, &c., the manuscript account and description of which are preserved in the Bodleian Library.

In the fifteenth century, Walther, of Nuremburg, was the first who made use of clocks in his astronomical observations And to Huyghens are we indebted for the application of pendulums to clocks, although mechanical constructions with weights had been used to measure time as early as the thirteenth century. Galileo also conceived the idea of using the pendulum, but could not accomplish his scheme, because he endeavored to make the pendulum the prime mover.

In the sixteenth century Nonius invented some useful instruments, and greatly improved others, among which are the astronomical quadrant. He divided this

instrument into degrees and parts more accurately than had before been conceived possible.

The instruments used by Tycho Brahé, in his observatory at Huen, are described as very complete. The quadrants were so accurately divided that the arc might be read off true to one-sixth of a minute. One of his quadrants was divided according to the method of Nonius.

CHAPTER III.

SECTION I.

From the Beginning of the Seventeenth to the End of the Eighteenth Century.

On the death of Tycho Brahé, in 1601, Kepler succeeded him as principal mathematician to the emperor. In 1606, he published a work on the optical part of Astronomy, entitled a "Supplement to Vitellius;" in 1609 appeared his New Astronomy, or *De Motibus Stellæ Martis;* and in 1611 he published his *Dioptrics*, in which he gives the theory of the telescope.

In 1618 he published his work entitled *Harmonices Mundi*, dedicated to James I. of England. This work contains his third law—"The squares of the periodic times of the planets are in proportion to the cubes of their mean distances from the Sun." Kepler had been seventeen years in search of this law, and when he discovered it, he was almost frantic with joy. "The die is cast," he exclaimed, "the book is written to be read either now or by posterity, I care not which. It may well wait a century for a reader, as God has waited 6000 years for an observer." In 1628 Kepler finished the *Rudolphine Tables*, founded on the laws which he discovered, and the observations of Tycho Brahé.

While Kepler was making his discoveries in the north, Galileo was no less occupied in the south of Europe, in his philosophical experiments. In the year 1609, while on a visit to a friend in Venice, he learned that a Dutchman of the name of Jansen had made an instrument which enabled persons to see at a greater distance than by the naked eye. By means of a telescope, which magnified thirty times, he discovered that the Moon is diversified with mountains and caverns; that the Sun, instead of being a ball of fire, is covered with irregularly-shaped black spots, and that it revolves on its axis; that the planet Venus exhibits phases resembling the Moon; that Jupiter is accompanied by four small stars or moons; and that Saturn, unlike all the others, is not round, but has two handles, as it were, at its sides, and which he afterwards thought were two small planets, one on each side of the large one. These handles, or ansæ, as they were called, were found to be the extremities of the ring, which Galileo's telescope was not sufficiently powerful to reveal. In the year 1617 he was charged with teaching the doctrine of the stability of the Sun and the annual motion of the Earth, which, being considered contrary to the Scriptures, caused the persecution and imprisonment of its author.

The telescopic discoveries of Galileo exercised such a withering influence upon the ancient philosophy, that many of its adherents refused to acknowledge the truths thus revealed to them. "Oh! my dear Kepler," says Galileo in one of his

letters, "how I wish we could have one hearty laugh together! Here, at Padua, is the principal professor of philosophy, whom I have repeatedly and earnestly requested to look at the Moon and planets through my glass, refuses to do so. What shouts of laughter we should have at this folly, and to hear the professor of philosophy in Pisa laboring before the grand duke with logical arguments, as with magical incantations, to charm the new planets out of the sky!"

The last telescopic observations of Galileo resulted in the discovery of the diurnal libration of the Moon. He was attacked soon after with a disease of the eyes, which in a few months rendered him totally blind. This sudden and severe calamity almost overpowered him, as he was thereby incapacitated for any future observations of the heavens. In writing to a friend, he says—"Alas! your dear friend and servant has become totally and irreparably blind. These heavens, this Earth, this universe, which, by powerful observation I had enlarged a thousand times beyond the belief of past ages, are henceforth shrunk into the narrow space which I occupy myself. So it pleases God; it shall, therefore, please me also."

In the early part of this century, Lord Napier invented logarithms, "which," says La Place, "by reducing the labors of months to a few days, doubles the life of the astronomer."

About the same time, Scheiner, a German astronomer, made numerous observations on the solar spots; and Bayer, of Augsburg, published a map and description of the constellations.

The elder Cassini was the contemporary of Huyghens, and a noted astronomer. He was the first professor in the Royal Observatory of Paris, and belonged to a family for more than 250 years illustrious in the scientific annals of France. Cassini constructed the first tables of Jupiter's satellites which were deserving of confidence. He discovered four of Saturn's satellites, the belts of Jupiter, and his rotation on his axis, and made many other important additions to science. Harriot also flourished about this time, to whom we owe many contributions to astronomical and mathematical science.

Horrox, a young English astronomer, in the year 1639 witnessed the first transit of Venus ever seen by man. Gassendi observed a transit of Mercury eight years previous.

One of the most indefatigable observers of those times was Hevelius, a rich citizen of Dantzic, who devoted his life and fortune to the service of his favorite science. He made drawings of the different phases of the Moon, which cost him years of labor. He also made numerous observations on comets, and concluded that as their orbits could not be circular, they must move in parabolas.

Huyghens added his share to the large stock of astronomical knowledge which was now accumulating through the exertions of some of the brightest intellects which the world has ever produced. Besides inventing some instruments, he discovered the ring of Saturn, and one of the satellites. As the number of satellites just equalled the number of planets then known, Huyghens considered it unnecessary to seek for any more, as the equality was necessary for the harmony of nature. This superstitious notion was common in those times, as may be seen by the writings of Kepler and others.

About this time Roemer discovered the progressive motion of light, and mea sured its velocity by means of the eclipses of Jupiter's satellites.

As astronomical knowledge had recently received such valuable accessions in the labors and inventions of those men of genius who flourished during the pre-ceding half century, it was deemed necessary to erect observatories, and furnish them with all the best apparatus, in order not only to encourage the increasing taste for this branch of science, but also to facilitate celestial observations. In the year 1670, the Royal Observatory of Paris was completed, and Dominic Cassini was invited by Louis XIV. to take charge of it. He enriched science by a number of valuable observations and discoveries, among which were tables of the motions and eclipses of Jupiter's satellites, the double ring of Saturn, and four more satellites belonging to that planet. He determined the rotation of Jupiter and Mars, besides many other discoveries: he made the first table of refractions. Cassini devoted his life chiefly in observing the appearances and motions of the heavenly bodies, which finally so affected his sight as to render him blind. The charge of the Paris observatory remained in the Cassini family during the period of 120 years.

The very year in which Galileo died, the great Newton was born. He discovered the cause of the precession of the equinoxes, and determined some of the principal lunar inequalities and planetary perturbations. In the year 1666, it is said, Newton first conceived the idea of gravitation from seeing an apple fall from a tree. This led him to attribute the retention of the Moon in her orbit to the same cause; a fact which his future calculations tended to confirm. He observed that the force of gravitation on the summits of the highest mountains is nearly the same as at the level of the sea; from which he inferred that the attractive influence of the Earth extends to the Moon, and, combining with her projectile force, retains her in her orbit round the Sun. Hence followed the inference that if terrestrial gravitation retains the Moon in her orbit, solar gravitation must be the principle which influences the planets, when combined with their projectile forces, to perform their revolutions round the Sun. This theory he proved to be true by showing the areas are proportional to the times.

When in his 30th year, Newton was proposed as a Fellow of the Royal Society. On being informed of the fact, he remarked to the secretary that he hoped he would be elected, and added that he "would endeavor to testify his gratitude by communicating what his poor and solitary endeavors could effect towards promoting their philosophical designs." Soon after his election, he communicated to the society a paper on the composition and decomposition of light, and his theory of colors. About this time he resided next door to a widow lady, who was much puzzled by the peculiarities of the philosopher. On one occasion, a Fellow of the Royal Society happening to call upon her, she remarked that "in the adjoining house a poor *crazy gentleman* had come to reside, who diverts himself in the oddest ways imaginable. Every morning, when the Sun shines so brightly that we are obliged to close the window blinds, he takes his seat in front of a tub of soap-suds, and occupies himself for hours blowing soap-bubbles through a common pipe, and watching them intently till they burst. He is doubtless now at his favorite amusement," she added; "do come and look at him." The gentleman, looking

into the adjoining yard, turned round and said—"My dear madam, the person whom you suppose to be a poor lunatic is no other than Newton, the great philosopher, studying the refraction of light upon thin plates, a phenomenon which is beautifully exhibited upon the surface of a common soap-bubble." This anecdote serves as an excellent moral, teaching us not to ridicule what we do not understand, but gently and industriously to gather wisdom from every circumstance around us.

Newton was the author of many works, the principal of which was his *Principia*, which is destined to stand as a monument of his genius. The following remarks by Mr. Whewell tend to enhance the admiration and wonder with which the immortal discoverer of universal gravitation will always be regarded:—"No one, for sixty years after the publication of the *Principia*, and with Newton's methods,—no one, up to the present day, has added any thing of any value to his deductions. We know that he calculated all the principal lunar inequalities; in many of the cases he has given us his processes, in others only his results. But who has presented in his beautiful geometry, or deduced from his simple principles, any of the inequalities which he left untouched? The ponderous instrument of synthesis, so effective in his hand, has never since been grasped by one who could use it for such purposes; and we gaze at it with admiring curiosity, as on some gigantic implement of war which stands idle among the memorials of ancient days, and makes us wonder what manner of man he was who could wield as a weapon what we can hardly lift as a burden." This immortal genius, who contributed probably more than any other man to the extension of human knowledge, felt no difference between his own mind and that of other philosophers. In a letter to a friend, he says—"If I have done the public any service, it is due to nothing but industry and patient thought." It is said of him, that while preparing his Principia, he lived only to calculate and think.

The Greenwich Observatory was erected in 1675, and Flamsteed was appointed to the charge of it, which office he filled for upwards of 30 years. He published a catalogue of 2284 stars, made many observations on the fixed stars, planets, comets, and spots on the Sun, &c. His labors were chiefly confined to the practical part of Astronomy.

Edmund Halley, the son of a wealthy citizen of London, from his earliest years devoted himself to the study of Mathematics and Astronomy. While only in his 19th year, he made some discoveries with regard to the orbits of the planets, and soon after undertook a voyage to the island of St. Helena, in order to make a catalogue of stars in the southern hemisphere. He revived the old theory that comets belong to the solar system, and ventured to predict that the comet of 1681 would return in the year 1759, which was verified; the return having occurred 17 years after his death. In advising astronomers to watch for its reappearance, Halley expressed a hope that in the event of its return they would acknowledge its periodicity had been discovered by an Englishman.

On the death of Flamsteed, in 1719, Halley was appointed to fill his office in the Greenwich Observatory. It is to Halley that posterity is indebted for Newton's Principia; for had it not been for his earnest solicitations, Newton would not have given that great work to the world.

Towards the close of the seventeenth century, Bradley, the successor of Halley, astonished the world by his sagacious observations. There had been an annual apparent motion observed in the polar and circumpolar stars by many astronomers, which had never been satisfactorily explained. Bradley, at last, after much deliberation, determined it to be owing to the motion of light combined with the annual motion of the Earth. This discovery, called the aberration of light, was made in the year 1728. He afterwards discovered *nutation*, which, with the former discovery of aberration, entitles him to a high place among the list of astronomers.

While Bradley was distinguishing himself in England, Lacaille was laboring successfully in the same cause in France. In 1751 he made a voyage to the Cape of Good Hope for the purpose of determining the Sun's parallax, and to form a catalogue of the southern circumpolar stars. He observed more than ten thousand stars situated between the Tropic of Capricorn and the pole, of which he computed the places of 1942. This herculean task was performed in the incredibly short period of *one year*. He also made many other important astronomical observations.

Another genius of extraordinary powers now appeared on the stage. This was William—afterwards Sir William—Herschel. He rendered his name immortal by the discovery, in the year 1781, of another member, beyond the limits formerly assigned to our system. This body was first named *Georgium Sidus*, in honor of his patron, but the name of Uranus is now preferred. By means of more powerful telescopes than any then known, he discovered the belts of Saturn, and two more satellites belonging to that planet. His observations on double stars and nebulæ have opened a new field for the astronomer. He was assisted in his labors by his sister, Miss Caroline Herschel, whose name should be enrolled among the observers of that day.

Miss Herschel was the constant companion of her brother, and the sole assistant of his astronomical labors, to the success of which, her indefatigable diligence and singular accuracy of calculation greatly contributed. In the intervals, she found time for observations and discoveries of her own, among which were no less than eight comets, besides many nebulæ and clusters previously unobserved. As a reward for these labors, King George III. placed her in receipt of a salary quite sufficient for her singularly moderate wants and retired habits.

In speaking of Miss Caroline Herschel, Dr. Nichol says—"The astronomer, (Sir William Herschel,) during these engrossing nights, was constantly assisted in his labors by a devoted maiden sister, who braved with him the inclemency of the weather—who heroically shared his privations, that she might participate in his delights—whose pen, we are told, committed to paper his notes of observations as they issued from his lips; she it was who, having passed the nights near the telescope, took the rough manuscripts to her cottage at the dawn of day, and produced a fair copy of the night's work on the ensuing morning; she it was who planned the labor of each succeeding night, who reduced every observation, made every calculation, and kept every thing in systematic order; she it was—Miss Caroline Herschel—who helped our astronomer to gather an imperishable name. * * * Some years ago the gold medal of our astronomical society was trans-

mitted to her at her native Hanover, whither she removed after Sir William's death; and the same learned society has recently inscribed her name upon its roll. But she has been rewarded by yet more—by what she will value beyond all earthly pleasures: she has lived to see her favorite nephew—him who grew up under her eye unto an astronomer—gather around him the highest hopes of scientific Europe, and prove himself fully equal to tread in the footsteps of his father."—*Dr. Nichol's Architecture of the Heavens.*

Miss Herschel died at Hanover in the year 1848, in the 98th year of her age.

Contemporary with Herschel, lived Piazzi, at Palermo, where he established an observatory, which was furnished with the best instruments. He was an accurate observer, and made for himself a great name.

SECTION II.

Astronomical Instruments in Use from the Beginning of the Seventeenth to the End of the Eighteenth Century.

The epoch under consideration is a period noted for the improvements and inventions of astronomical instruments.

The collection of instruments at Uranibourg, belonging to Tycho Brahé, was the finest which had ever been made. His mural quadrant, of five cubits radius, was noted for its minute graduation.

Cassini erected a gnomon in the church of St. Petronius, at Bologna, which was 83 French feet in height.

The first telescope made by Galileo, in the early part of the seventeenth century, was formed by the combination of a plano-convex and plano-concave lens fitted in a leaden tube. This instrument magnified only about three times. He made another, which magnified about eight times, which giving him encouragement for further effort, he succeeded in making one with a power of more than thirty. With this telescope he made those observations mentioned in the first part of this chapter.

Huyghens directed his attention most particularly to optics. He made a telescope of ten feet, by means of which he discovered one of the satellites of Saturn. He applied the pendulum to clocks, which may be considered as a valuable gift conferred on the science of Astronomy. He was the first to determine what should be the length of a pendulum whose vibrations should each be performed in a second of time.

Gascoigne originated some improvements in practical Astronomy. He was the first person who introduced the use of telescopic *sights*, and was the inventor of the micrometer. But to Huyghens, Malvasia, and Azout are we indebted for the application of the micrometer to the telescope.

Picard introduced the application of telescopes and micrometers to graduated instruments. In 1669, he constructed a quadrant, to which he applied an astronomical telescope, which he made use of to observe the stars on the meridian in the daytime. This telescope had cross-wires in its focus. But Huyghens had invented the plate micrometer nearly twenty years before.

These great improvements in instruments gave an impulse to astronomical discovery which had not been known before, and which threatened to overthrow old, preconceived notions. Hevelius refused to make use of them, because they would make all the old observations of little value, and render useless the results of a long life of arduous labor.

Picard was the first person who determined the right ascensions of the stars by observing their meridian transits. In these observations he always made use of the pendulum.

In the year 1644, Roemer, a Danish astronomer, introduced the method of observing the right ascension of celestial bodies by means of a transit instrument; that is, a telescope attached to a horizontal axis perpendicular to its length, and movable only in the plane of the meridian.

Graham executed a large mural arc for Halley, at Greenwich; and also a sector for Bradley, with which he detected aberration.

Molyneux and Bradley commenced a series of observations in 1725, with a zenith sector whose radius was 24 feet.

Astronomy received a strong impulse during this period by the erection of public observatories—the first of which is the Royal Observatory of Copenhagen, in 1656; second, the Royal Observatory of Paris, in 1667; after which is the Royal Observatory at Greenwich, in 1675. To James Gregory we owe the invention of that form of the reflecting telescope which bears his name. In 1786, Louis XVI. directed M. de Beauchamp to superintend the erection of an observatory at Bagdad, which bore the inscription—"Built to restore the Chaldean and Arabian observations."

About the year 1767, Bird, an English artist, divided several quadrants for public observations, which were so accurately done that the English government purchased from him the secret.

Ramsden, another artist, was also very successful. He made a quadrant, which was sent to Padua, the greatest error of which never exceeded two seconds. In 1788, Ramsden made a mural circle for M. Piazzi, at Palermo, which was five feet in diameter; and one of eleven feet in diameter for the Dublin Observatory.

Huyghens, in his first attempt at constructing telescopes, made one 22 feet long. But this was eclipsed by those of Campani, who, by order of Louis XIV., made them of 86, 100, and 136 feet in length. After this, Huyghens constructed one of no less than 210 feet in length. Azout and Hartsoecker are said to have made an object-glass of 600 feet focus, which certainly must have been unmanageable. Some of the object-glasses of Huyghens and Cassini were placed upon a pole, and the observer seated himself at the focus with an eye-glass, there being no tube to the telescope.

The principal improvement in the telescope was the construction of lenses formed of glass possessing different degrees of refractive power, in which the chromatic aberration was almost entirely removed, and the spherical aberration materially diminished. This invention, called the *achromatic telescope*, is due to Mr. Dollond. Dollond and his son succeeded in constructing telescopes 3 feet long, with a triple object-glass, which produced an effect as great as those of 45 feet on the old principle.

CHAPTER IV.

History of Astronomy from the Beginning to the Middle of the Nineteenth Century.

The first day of the nineteenth century was ushered in by the discovery of a new planet between the orbits of Mars and Jupiter. This body was discovered by Piazzi, at Palermo, on the 1st of January, 1801, and is named Ceres. The next year, 1802, witnessed the discovery of another small planet by Dr. Olbers, which he named Pallas. In 1804, Harding discovered a third in the same region, to which he gave the name of Juno; and in 1807, Dr. Olbers discovered a fourth, which he called Vesta. These small bodies are known by the name of asteroids, only four of which were seen from 1807 until 1845, no other asteroids being then known to exist. By referring to the table of those bodies, and the dates of their discoveries, in Part II. Chapter V. Section II., a full description of them will be found.

During the first half of this century, the attention of astronomers has been turned to comets; many valuable observations have been made with regard to the orbits and movements of these bodies, a full account of which may be found in another part of this work.

The discovery of a primary planet, yet more distant than Uranus, is another prominent feature in the discoveries of this century.

M. Le Verrier, from theory alone, was enabled to fix on almost the precise spot where this body might be found, fully verifying the predictions so confidently asserted, and triumphantly proving the certainty of mathematical calculations.

The discoveries during this century are fully given under their proper heads in another part of this work, as well as the astronomers who have thus distinguished themselves. The observatories of Washington, Cambridge, and Cincinnati, as well as many in Europe, are doing honor to their respective countries by the means which they afford for the rapid advancement of the science of Astronomy.

A description of the principal astronomical instruments now in use is given under Part IV.

There is a galaxy of astronomers at the present day in Europe, as well as in our own country, to whom we are indebted for many valuable acquisitions to our fund of astronomical knowledge. The names of Struve, Herschel, Le Verrier, Smyth, Hind, Gauss, Airy, Rosse, Bond, Alexander, Maury, Gould, Olmsted, Peirce, and many others, who have contributed largely to astronomical science, will ever be regarded among the brightest stars of the nineteenth century.

NOTES.

Divisibility of Matter.

NOTE 1, PAGE 16.

As far as our experience goes, we find that all bodies may be divided and subdivided even beyond the limits of sensible perception.

A single grain of gold may be divided into many millions of parts, visible by the aid of the microscope. The gold which covers the silver wire used in making gold lace is beaten out so that a single grain would cover a surface of nearly thirty square yards. In odoriferous bodies, such as musk, an apartment may be filled year after year with the most intensely penetrating odor, without any perceptible loss of weight.

In cinnabar may be found another example of the divisibility of matter. It is composed of mercury and sulphur, and may easily be separated into these constituents; yet, says Professor Müller, under the best microscopes it appears to be a perfectly homogeneous mass, the small particles of sulphur and mercury being undistinguishable.

But although divisibility extends far beyond the limits of our senses, it must not be inferred that it is wholly unlimited. Those minute particles of matter which cannot be further disintegrated are, by philosophers, termed atoms.

Galileo's Experiment.

NOTE 2, PAGE 18.

ARISTOTLE, more than two thousand years ago, taught, among other philosophical errors, that if two bodies of unequal weight were to be let fall from the same height, at the same moment, the heavier body would move as much swifter than the lighter as its weight exceeded that of the lighter body. Galileo, a great Italian philosopher and astronomer, discovered the fallacy of this theory, and, on subjecting it to experiment, proved beyond a doubt that the velocities of falling bodies do not depend upon their weight. As may be supposed, Galileo met with opposition from all sides in the promulgation of his new philosophy. His opponents of the Aristotelian school accepted a challenge from him to submit their respective theories to the public test. The celebrated Leaning Tower of Pisa was chosen for the performance of the experiment. At the time appointed, each party repaired to the spot, equally confident of success. The experiment was made with two balls, the one precisely one-half the weight of the other. The followers of Aristotle asserted that the heavier ball would reach the earth in one-half the time it would require the lighter one to descend; and Galileo maintained that the difference of weight would not affect their velocities, but that they would

both reach the ground at the same moment. On the day appointed, in the presence of a large concourse of people assembled to witness the performance, the experiment was made, and Galileo came off victor, both balls having touched the ground at the same instant.

Gravitation, and Progress of its Discovery.

NOTE 3, PAGE 18.

THERE is no doubt that Plato had a clearer idea than Aristotle of the attractive force exercised by the Earth's centre on all matter removed from it. Aristotle, as well as Hipparchus, was acquainted with the acceleration of falling bodies, without correctly comprehending the cause. Plato, as well as Democritus, conceived there was attraction between bodies whose elements were homogeneous.

John Philopenus, the Alexandrian, a pupil of Ammonias, who was a philosopher of the eclectic school, flourished in the fifth or sixth century of our era. He was the first who ascribed the movements of the heavenly bodies to a primitive impulse; connecting with this theory that of the fall of bodies, or the tendency of all substances, whether heavy or light, to reach the Earth.

Kepler, in his work *De Stella Martis*, observes that "two insulated bodies would move towards each other like two magnets, describing spaces reciprocally as their masses; and that if the Earth and Moon were not held by some force at the distance which separates them, they would come in contact. The Moon, being the smaller body, would describe $\frac{53}{54}$ of the distance, and the Earth the remaining $\frac{1}{54}$, supposing them to be of equal density. If the Earth ceased to attract the waters of the ocean, they would be drawn to the Moon by the attractive force of that body. The attraction of the Moon, which extends to the Earth, is the cause of the ebb and flow of the sea."

Thus *De Stella Martis* contains the germ of the theory of gravitation, which the genius of Newton developed.

The idea expressed by Kepler, of the ebb and flow of the ocean being caused by the attractive influence of the Moon, received in 1666 and 1674 a fresh impulse and a more extended application through the sagacity of the ingenious Robert Hooke, a noted experimental philosopher, who distinguished himself by numerous discoveries in science. But Newton's theory of gravitation, which followed these earlier advances, presented the grand means of converting the whole of Physical Astronomy into a true mechanism of the heavens. This great philosopher observed that the force of gravitation on the summits of the highest mountains is nearly the same as at the level of the sea; from which he inferred that the attractive influence of the Earth extends to the Moon, and combining with her projectile force, retains her in her orbit around the Earth. Hence followed the inference that if terrestrial gravitation retains the Moon in her orbit, solar gravitation must be the principle which influences the planets, when combined with their projectile forces, to perform their revolutions round the Sun. This theory he proved to be true, by showing that the areas were proportional to the times.

Notwithstanding the theory of gravitation was proved by Newton, it was attained by means of such intricate reasoning as soared far above the reach of ordinary

minds; consequently, a very small number of mathematicians were qualified to appreciate the evidence upon which the conclusions of Newton were founded, the methods adopted being almost exclusively the creation of his own genius. From this cause the doctrines of the "Principia" were long neglected, and afterwards violently opposed, particularly on the continent of Europe. Huyghens, notwithstanding his high admiration for the genius of Newton, was one of the strong opponents of the theory of universal gravitation. Although he admitted the mutual gravitation of the planets and satellites, according to the law of the inverse square of the distance, he could not be persuaded to assent to the doctrine of the mutual attraction of the parts of which those bodies are composed. In one of his works, in allusion to Newton's theory of the figure of the Earth, he says it is inadmissible, inasmuch as it supposes that all particles of matter have an affinity for each other; which, he says, cannot be reconciled with the established laws of mechanics.

In Germany, the great Leibnitz was a formidable opponent of the Newtonian theory. He embraced the opinions of Descartes with regard to the planetary motions.

In France, Cassini and Maraldi were strenuously opposed to the new philosophy, and their example was generally followed by contemporary astronomers. It was not until about the middle of the eighteenth century that the theory of gravitation was confirmed beyond any doubt.

The illustrious discoverer of this universal law claimed no particular talents above other inquirers into the secrets of nature. In a letter to Dr. Bentley, Newton said—"If I have done the public any service in philosophical discoveries, it is due to nothing but industry and patient thought."

As far as human knowledge extends, the intensity of gravitation has never varied within the limits of the solar system, nor does even analogy lead us to expect that it should; on the contrary, there is every reason to believe that the great laws of the universe are immutable, like their Author.

Centre of Gravity.

NOTE 4, PAGE 20.

THE discovery of the centre of gravity is due to Archimedes; many skilful geometricians endeavored to discover its position, both in plane surfaces and solids. Euler, believing it to depend only on the figure of the body, called this point the *centre of inertia;* it may also be called the *centre of parallel forces.*

Laws of Motion.

NOTE 5, PAGE 22.

A CANNON ball of a *thousand ounces,* moving one foot per second, has the same quantity or force of motion as a musket ball of *one ounce,* leaving the gun barrel with the velocity of a *thousand feet* in a second.

From these general principles flow directly three axioms, called the *laws of motion.* These are termed Newton's Laws, but they first appeared in *Descartes's Principia Philosophiæ,* Part II. p. 38, a work which appeared before *Newton's Principia.*

These three laws are as follows:—

Law I. *Every body perseveres in its state of rest, or uniform motion in a straight line, unless it is compelled to change that state by forces impressed thereon.*

When a body is at rest, it would remain so forever, if it were not put in motion by some external force. If a cannon ball be shot in a certain direction, it would continue to move in a straight line, if it were not checked by the resistance of the air, and drawn to the earth by the force of gravity.

Law II. *The alteration of motion, or motion generated or destroyed in any body, is proportioned to the force applied; and is made in that straight line in which the force acts.*

If a certain motion be generated by a given force, a double motion would be produced by a double force, if both forces operate in the same direction. If a body be acted on by two equal forces in different directions, it will take a direction differing from both, and intermediate between the two. But if it be acted on by two equal forces in opposite directions, the body will remain in a state of rest; the two forces, being equal, will neutralize each other.

Law III. *To every action there is always opposed an equal reaction; or the mutual actions of two bodies upon each other are always equal and directed to contrary points.* (See Newton's Principia, Book I.)

If there be a pound weight in one scale, we must use the force of a pound to raise the weight.

Centrifugal Force.

Note 6, Page 26.

We have, in all circular motions, the example of a continued acting force. The motion of matter abandoned to itself would be uniform and rectilinear; it is evident, therefore, that a body moving in a circle has an increasing tendency to fly off from the centre at a tangent. In circular motion, the *central* or *centripetal* force is equal and directly contrary to the *projectile* or *centrifugal force.* The former attracts the body to the centre, and in a very small interval of time its effect may be measured by the versed sine of the arc described.*

As the centrifugal force is increased by increasing the velocity of a revolving body, if the Earth were to revolve more rapidly on her axis than she now does, the force of gravity would be diminished.

The force of gravity at the equator is known to be 289 times greater than the centrifugal force; and as 289 is the square of 17, it follows that if the Earth were to revolve 17 times faster than she now does—that is, to complete her revolution in 85 minutes instead of twenty-four hours—the centrifugal force would be entirely neutralized. In this case the centrifugal force would be equal to that of gravity, and bodies at the equator would have *no weight.* But suppose the Earth were to complete a diurnal revolution in a still less time than 85 minutes, all small and light substances would fly off from the surface; and if the velocity were greatly increased, the more massive portions of the Earth's surface would fly off and rotate around it.

---

* La Place, *Système du Monde,* Liv. III. chap. ii.

Angular Measurement.

NOTE 7, PAGE 28.

IT is manifest that our sight can give us no other information regarding the bodies which are distributed in space around the Earth, than the facts of their apparent positions and dimensions. These can only be exactly determined by means of angular measurement; that is, by noting the amount of divergence that separates the straight lines along which they are severally viewed. The astronomer first carefully and accurately ascertains the apparent positions of the heavenly bodies and their apparent dimensions in this way, and then from the apparent positions and dimensions which he has observed, he deduces their real sizes and distances, and also their true arrangements and motions in space.

It must be borne in mind that *apparent* dimensions and positions are very different from *real* dimensions and positions. The former are merely the rough elements by means of which the latter may be found through a complicated process. The apparent size of a body is the amount of divergence by which two straight lines are separated, coming to the eye from either of its extremities. In the same way the apparent positions of two bodies are merely the amount of divergence by which two straight lines are separated, coming to the eye from each of them.

It will be understood that when a planet, the Sun, or Moon are said to appear so many degrees, minutes, or seconds from each other, those degrees, minutes, or seconds have always been merely the corresponding proportional parts of the great circle of the heavens used as standards of comparison.

Atmosphere of the Sun, and Solar Spots.

NOTE 8, PAGE 31.

THE resplendent nature of the Sun is now supposed to arise from a luminous atmosphere, or photosphere, as it has been termed, which is the source of light and the partial cause, at least, of heat, throughout the system. Of the precise nature of this envelope we are yet ignorant, but that it exists is almost beyond dispute, from the appearances revealed by the telescope.

It is conjectured that there are three atmospheric strata about the sun: that supposed to lie nearest his surface is called the *cloudy stratum*, being of a character incapable of reflecting light, and heavily loaded with vapors; the next in elevation is thought to consist of an intensely luminous medium, and to this is attributed the diffusion of light and heat; at a greater altitude still, it is probable there exists a third envelope of a transparent gaseous nature.

Sir John Herschel says, "Above the luminous surface of the Sun there are strong indications of the existence of a gaseous atmosphere, having a somewhat imperfect transparency. When the whole disc of the Sun is seen at once through a telescope magnifying moderately enough to allow it, and with a darkening glass, such as to suffer it to be contemplated with perfect comfort, it is very evident that the borders of the disc are much less luminous than the centre. This can only arise from the circumferential rays having undergone the absorptive action of a much greater thickness of some imperfectly transparent envelope (due to the greater obliquity of their passage through it) than the central. But a still

more convincing, and indeed decisive evidence, is offered by the phenomena attending a total eclipse of the Sun, which prove the existence of an atmosphere as above described." *Herschel's Ast.* p. 209.

When viewed through the telescope, the Sun has the appearance of an enormous globe of fire, the surface of which appears mottled or grained, and frequently in agitation. Irregularly-shaped black spots are sometimes to be seen on his disc, grouped together, as in the following figure.

Fig. 198.

Spots of this kind have been known to be so large as to be distinguished by the naked eye. One is recorded as having been seen by Sir William Herschel in 1779, which was 30,000 miles in diameter. The spots appear to move from east to west on the Sun's disc in about fourteen days. Dark spots are usually surrounded by a penumbra, and that again by a margin of light brighter than the other parts of the disc. When a spot is first seen on the eastern edge of the Sun, it appears like a line, which enlarges in breadth until it reaches the middle of the disc, when it begins to contract, and finally disappears on the western limb. After a space of fourteen days, they have been known to reappear on the east side.

The spots often retain their form for several days without material change, and sometimes only a few hours are required to witness astonishingly rapid changes in them. A large spot has often been seen to separate, and, as it were, break into small fragments, in the space of a few minutes. Small spots, too, sometimes coalesce and form one large one in a very short space of time.

The paths which the spots describe about the beginning of June and December are observed to be rectilinear. But from the month of June to December, the lines described are convex to the north; and from December to June, the line of spots is convex to the south. From these circumstances, it has been conjectured that the spots are attached to the surface of the Sun, and that the Sun rotates on his axis, which is inclined 7° 30′ to the axis of the ecliptic.

Sir William Herschel supposed the Sun to be a solid, dark nucleus, surrounded by a vast atmosphere, almost always filled with luminous clouds, occasionally opening and discovering the dark mass within. The speculations of La Place were—that the solar orb is a mass of fire, and that the violent effervescences and ebullitions seen on its surface are occasioned by the eruption of elastic fluids formed in its interior; and that the spots are enormous caverns, like the craters of our volcanoes.

The light is more intense at the centre of the Sun's disc than at the edges, although, from his spheroidal figure, the edges exhibit a greater surface than the centre under the same angle. This fact is accounted for, on the supposition that

the Sun is surrounded by a dense atmosphere, which absorbs a portion of the rays, which have to penetrate a greater extent of it at the edges than at the centre. The reverse is the case with the Moon, which is supposed to be devoid of an appreciable atmosphere, for the light at the edges of her disc is more brilliant than at the centre.

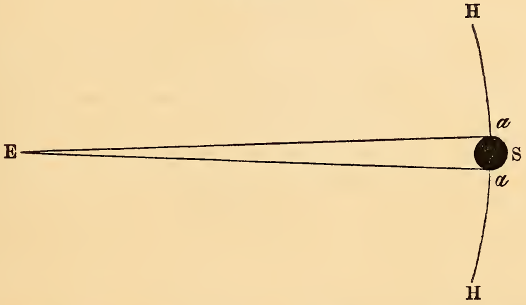
Diameters of the Planets Measured.

NOTE 9, PAGE 40.

"THE apparent diameters of the Sun, Moon, and planets are determined by measurement; therefore their real diameters may be compared with that of the Earth: for the real diameter of a planet is to the real diameter of the Earth, or 7916 miles, as the apparent diameter of the planet to the apparent diameter of the Earth as seen from the planet: that is, to twice the parallax of the planet." *Mrs. Somerville, Con. Phys. Sci.*, p. 55.

When the apparent size and real distance of a body are known, it is easy to calculate its true dimensions.

Fig. 199.



Let *a a* represent the diameter of the Sun S, and E *a* E *a* its distance from the Earth. Then *a* E *a* is a triangle, of which two sides and one angle are known: the angle E being the apparent breadth of the Sun's disc, compared with the entire circle of the heavens, of which H H is an arc. The angular measurement of the Sun is 32′ 3″, or 1923″ out of the 1,296,000″ which the entire circumference of the heavens contains. The sides E *a* E *a* are each the Sun's distance; that is, 95,000,000 of miles. But when two sides and one angle of a triangle are known, the third side can be calculated. Hence, the side *a a*, which is the Sun's diameter, has been found to be about 888,000 miles. The planets are measured in the same manner.

Seasons of Venus.

NOTE 10, PAGE 41.

IT is generally believed that the planet Venus is inclined to the plane of her orbit at an angle of 75°. It is well known that the inclination of the axis of the Earth is 23° 28′. Now, it is the inclination of the axis of a planet to the plane of its orbit which constitutes the annual viscissitudes known as the seasons.

On the 21st of March the days and nights are equal all over the Earth, the Sun being then vertical at the equator. From that time till the 21st of June the days increase in length in the northern hemisphere. On the 21st of June, the Sun arrives at the Tropic of Cancer, his greatest northern declination, which is 23° 28′ north of the equator; at which time the days are longest in the northern hemisphere. He then seems to recede southward until the 21st of September, when he is vertical again at the equator; at which time the days and nights are equal all over the Earth. From the 21st of September the Sun seems still to recede farther south, until the 23d of December, when the days are shortest in the northern hemisphere. Thus, it will be seen that the Sun is always vertical to some places in the torrid zone; and that the boundaries of that zone, called the tropics, are his utmost northern and southern declinations.

Fig. 200.

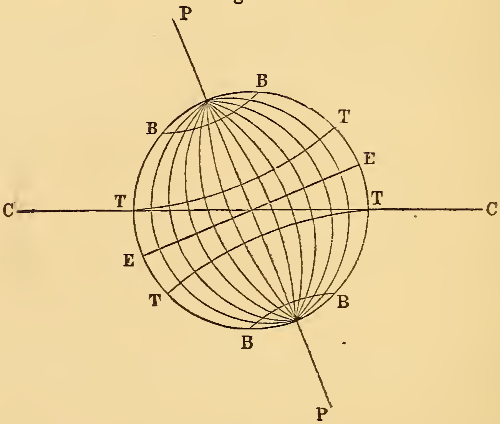
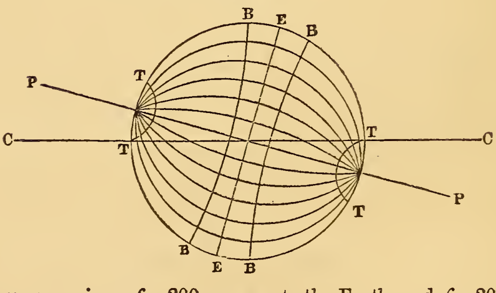


Fig. 201.



Of the above engravings, *fig.* 200 represents the Earth, and *fig.* 201, the planet Venus. C C are the planes of their respective orbits, P P their poles, and E E their equators. P P represent their axes as well as their poles. By referring to the figures, it will be seen that the axis of Venus is much more inclined from the perpendicular of her orbit than that of the Earth. T T indicates the tropics in

the two planets. It will be remembered that the tropics are the utmost limits at which the Sun is vertical. Now, on the planet Venus the tropics being within $16\frac{1}{2}°$ of her poles, it follows, that the Sun is at one time or other vertical to nearly all the points on her surface. As the tropics are the boundaries of the torrid zone, and as they are situated $73\frac{1}{2}°$ on each side of the equator, the torrid zone on the planet Venus must be 147° in width. As the tropics are within 15° of her poles, her polar circles must be within $16\frac{1}{2}°$ of her equator.

By this arrangement, the Sun is vertical twice a year to all places on the planet Venus, except those situated within $16\frac{1}{2}°$ of each pole. During one-half of Venus's year—that is, sixteen weeks—the Sun continues at one pole without setting, while the inhabitants of the other pole are involved in darkness. In this respect Venus resembles our Earth, for each pole has a night of half a year. But, unlike the Earth, the inhabitants at Venus's equator have two winters and two summers in every year. Let it be remembered that Venus's year is only about thirty-two of our weeks.

Form of the Earth.

NOTE 11, PAGE 45.

THE form of the Earth, as well as that of the planets and satellites, is owing to the reciprocal attraction of their component particles. For instance, a fluid mass, of any size whatever, if in a state of rest, would assume a spherical form, owing to the reciprocal attraction of its component particles. But if it be made to revolve on an axis, it at once becomes a spheroid, more or less flattened at the poles in proportion to the velocity of its axial rotation; for the centrifugal force arising from this velocity diminishes the gravity of the particles at the equator, which recede from the centre till by their number and attraction they counterbalance the centrifugal force.

The form of the Earth furnishes a standard of the weights and measures in ordinary use. The British measure of length is formed by noting the length of a pendulum vibrating seconds in the latitude of London. Its length was found by Captain Kater to be 39·1387 inches, when oscillating in vacuo at the temperature of 62° Fahrenheit, and reduced to the level of the sea. The weight of a cubic inch of distilled water, at the same temperature, and the barometer 30 inches, was also determined in parts of an imperial Troy pound; from these data the British standard of weight and measure can always be known.

The French have adopted the metre for their unit of linear measure, which is the ten-millionth part of that quadrant of the meridian passing through Formentera and Greenwich, the middle of which is nearly in the forty-fifth degree of latitude.

The Ellipse.

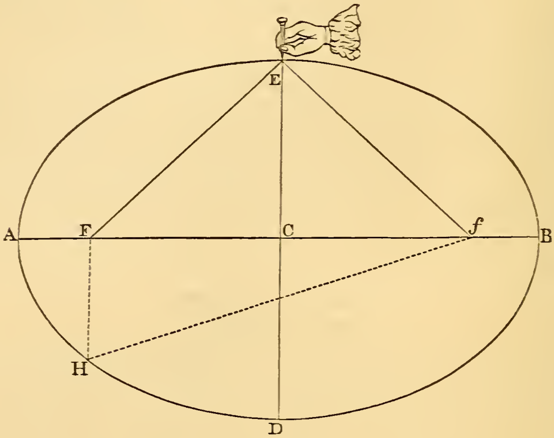
NOTE 12, PAGE 47.

THE ellipse, popularly called an *oval*, is one of the conic sections. The name of ellipse was given to it by Appolonius, among the ancients the first and principal writer on the conic sections.

This figure is variously defined by different authors, either from some of its

properties, from its mechanical construction, or from the section of a cone, which is the best and most natural method. Thus: An ellipse is a plane figure made by cutting a cone obliquely, by a plane passing through its opposite sides.

Fig. 202.



In order to construct an ellipse, the simplest method is to take a loop of thread of the length of the longer axis, fasten two pins (which represent the focal points of the ellipse) through the paper on a board, and pass the loop of thread over them; then place a pencil inside of the loop, stretch it with the pencil, and trace round the pins: the pencil will describe a curve called an ellipse.

In the above figure let F *f* be the pins, and F C *f* E the loop of thread; by stretching out the loop, as at E, with a pencil, the ellipse A E B D may be traced.

The line A B is the longer or transverse axis, the perpendicular to which, D C E, is the conjugate axis. F *f* are the two focal points or foci of the ellipse, and C, the intersection of the transverse and conjugate axes, is the centre.

The ellipse is a figure of such a nature that if two lines be drawn from two certain points in the axis to any point in the circumference, the sum of these two lines will be everywhere equal to the transverse axis.

If the two dotted lines F H *f* H be drawn from the points F *f* on the transverse axis to a point H in the circumference, the sum of these two lines will be found equal to the axis A B. The sum of the lines F E *f* E will also be found equal to the transverse axis A B, and also to the sum of the dotted lines F H *f* H.

Kepler's Laws.

Note 13, Page 48.

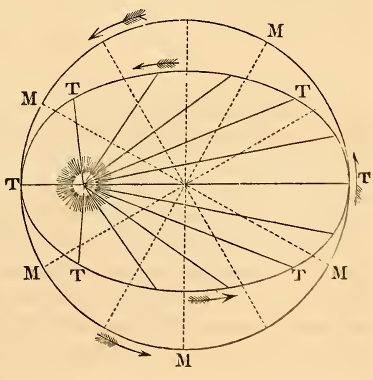
A planet moves in its elliptical orbit with a velocity varying every instant, in consequence of two forces: the one tending to the centre of the Sun, and the other in the direction of a tangent to its orbit arising from the primitive impulse given at the time when it was launched into space. Should the force in the tan-

gent cease, the planet would fall to the Sun by its gravity. Were the Sun not to attract it, the planet would fly off in the tangent. Thus, when the planet is at the point of its orbit farthest from the Sun, his action overcomes the planet's velocity, and brings it towards him with such an accelerated motion that at last it overcomes the Sun's attraction and shooting past him, gradually decreases in velocity until it arrives at the most distant point, where the Sun's attraction again prevails. In this motion the *radii vectores*, or imaginary lines joining the centres of the Sun and the planets, pass over equal areas or spaces in equal times.

In a circle the radii are all equal; but in an ellipse (*fig.* 45, page 48) the radius vector S *b* is greater, and S *a* less, than all the others. The radii vectores S *e* S *f* are equal to P *a* or P *b*, half the major axis *b a*, and consequently equal to the mean distance. A planet is at its mean distance from the Sun when in the points *f* or *e*. Thus it will be seen that a planet's mean distance from the Sun is equal to half the major axis of its orbit. If, therefore, a planet described a circle round the Sun at its mean distance, its motion and periodic time would be uniform, because the planet would arrive at the extremities of the major axis at the same instant, and would have the same velocity, whether it moved in the circular or elliptical orbit, since the curves coincide in these points.

Kepler, by a long series of observations, became convinced that the planetary orbits could not have the properties belonging to a circle, as had been conjectured by former astronomers. He selected the planet Mars as a subject for his investigations. He soon found that the predicted place of that planet was often far from the true one, which led him to seek for a new theory upon which to build his superstructure. He saw the fallacies of eccentrics and epicycles, and determined to try the next most simple curve—viz. the oval or ellipse. He placed the Sun in the *centre* of the major axis, hoping to follow out the planet through his elliptical orbit. But although at first he was flushed with success, he began to find that his hypothesis must be rejected. Finally, he placed the Sun in one of the foci of the ellipse instead of the centre, and was gratified to find his labors crowned with success. His theory was correct: he followed the planet Mars in his whole revolution, always finding him in the predicted place.

Fig. 203.



In *fig.* 203 the ellipse T T T, &c. represents the true orbit of the planet, and the circle M M M, &c. the *imaginary* orbit in which the mean place is designated. If the planets revolved in circular orbits, they would have a uniform motion; whereas, their motion is known to be sometimes faster or slower than a circular motion would be. At the extremities of the major axis—that is, at perihelion and aphelion—the mean and true motion is the same; for at these points the elliptical orbit and the *imaginary* circular one coincide.

By reference to the figure it will be

seen that from perihelion to aphelion the *true* places of the planet, which are designated by the plain lines diverging from the Sun and terminating at the circumference of the ellipse, are *ahead* or *eastward* of the mean places, which are designated by dotted lines diverging from the *centre of the circle*, and terminating at the circumference. From aphelion to perihelion the true place is *behind* the mean one.

The discovery of the elliptical orbit of Mars was soon followed by that of the other planets, and also of the Moon. Kepler, shortly after this, proclaimed to the world his "first law"—viz. *The planets revolve about the Sun in ellipses, having the Sun in one of the foci.*

As the planets were now known to move in elliptical orbits, and as their velocities varied in different parts of their orbits, it remained to discover the law which governs their movements. Kepler applied himself assiduously to the task, and was rewarded by discovering the law which regulates orbitual motions. This is called Kepler's "second great law." *If a line be drawn from the centre of the Sun to any planet, this line, as it is carried forward by the planet, will sweep over equal areas in equal portions of time.*

After seventeen years of incessant labor, Kepler discovered his third law. As the relative mean distances and periodic times of the planets were ascertained, Kepler thought there were certain mysterious analogies in the laws of nature, and endeavored to discover if any relation existed between their periodic times and their distances. After much patient research, he discovered that *the squares of the periodic times of the planets are as the cubes of their mean distances from the Sun;* which is known as Kepler's "third law."

The above laws of nature are now known as *Kepler's laws.*

"The laws of nature signify the enunciations of the method or will of God. If those who look coldly on science knew better its aims, we should have less of the infidelity of the term law, and find fewer infidels or rejecters of that revelation which God has spread out before us. To him whose mind has become deeply imbued with science, nature becomes a living expression, as full as is possible in finite language, of the perfection of the Supreme Architect, with whom to create has ever been to evolve beauty amid displays of wisdom and beneficence."—*Professor Dana's Address before the American Association for the Advancement of Science, August*, 1855.

The Asteroids.

Note 14, Page 57.

The bodies forming the group situated between the orbits of Mars and Jupiter, differ, in many respects, very widely from the other planets of the solar system. They are almost all telescopic, being too minute to be distinguished by the naked eye. They bear a strong resemblance to stars, even when viewed with a good telescope; which induced Sir William Herschel to give them the name of *Asteroids.*

The immense space existing between the orbits of Mars and Jupiter caused Kepler to suspect the existence of a planet, which idea was afterwards revived by the German astronomers, who took active measures to ascertain the fact. About this time Professor Bode announced the discovery of his law, an account of which is given in Note 15. So zealous were the German astronomers of that day to

throw light on this interesting question, that in the year 1800, six of them assembled at Lilienthal, and established a society consisting of twenty-four practical observers, whose duty it was to examine critically every telescopic star of the zodiac, in order, if possible, to discover the unknown planet.

On the first day of the following year, (1801,) their hopes were realized in the discovery of *Ceres*, by Piazzi, at Palermo. But Piazzi announced to the world that he had discovered a comet, the disc being but faintly determined, owing to the small diameter of the planet and its great distance from us.

Bode, however, immediately suspected its true nature, and from the slender data given by Piazzi its orbit was computed by Olbers, Burckhardt, and Gauss. This coincided very nearly with the computations of Baron de Zach for the orbit of the unknown planet; which, having been made by him from analogy in 1785, sixteen years previous, serves to show the triumph of the theory. This planet was called Ceres.

But what was the astonishment of these astronomers, when, in the following year, the discovery of another planet was announced by Dr. Olbers, of Bremen! And how much greater was their surprise, to find that this newly-discovered body, which they called *Pallas*, could not be restrained within the bounds of the zodiac, and that its orbit and that of Ceres approached so near, at the intersection of their planes, as to occupy but a narrow zone at the nodes! This fact led Dr. Olbers to suppose that they were the fragments of a larger body, which had been burst asunder by some great convulsion, and, if so, fragments of the body might yet be discovered.

This theory was strengthened in 1804 by the discovery of another small body, which M. Harding, its discoverer, called *Juno*. So convinced was Dr. Olbers in the truth of his theory respecting the common origin of these small planets, that as the mutual intersection of Ceres, Pallas, and Juno occurred in Virgo and Cetus, the explosion must have taken place in one of those regions, and therefore other fragments of this large body might be found there. His expectations were realized; for, in 1807, he discovered another small planet in the constellation Virgo, which was named *Vesta*.

After the discovery of this last-named planet in 1807, Dr. Olbers continued his search until the year 1816; when it was thought unnecessary to make any further observations in either of the above-named regions—namely, Virgo and Cetus—as no planetary body could have escaped the notice of observers. Therefore, the plan was relinquished for a time.

About the year 1830, M. Hencke, an amateur Prussian astronomer, undertook a survey of that zone of the heavens comprised between 15° on each side of the equator. He made himself so thoroughly acquainted with every minute telescopic star, that he could readily detect any planetary body in its orbit among them. After *fifteen years* of untiring diligence and unremitted labor, he discovered another small planet, which, having requested Professor Encke to name, he called *Astrea*. This planet was discovered in 1845, and in two years after, (1847,) M. Hencke announced the discovery of another asteroid, for which he requested Professor Gauss to select a name. *Hebe* was soon decided upon as the designation of the newly-discovered stranger.

In little more than a month after Hebe was introduced to the astronomical world, the distinguished English astronomer, Mr. Hind, at the private observatory of Mr. Bishop, in Regent's Park, London, discovered the seventh asteroid, which was named *Iris*. The same observer found another planet—the eighth in order of discovery—in about two months after he discovered Iris. This new planet was named *Flora*, by the request of Sir John Herschel.

In the spring of 1848, Mr. Graham discovered another planet, at the private observatory of Markree Castle, Ireland. The name selected for this little planet is *Metis*.

A year had not elapsed, before another member of this group was announced, by the name of *Hygeia*. Its discoverer was M. Annibal de Gasparis, assistant astronomer at the Royal Observatory at Naples.

In 1850, but a little more than a year after the discovery of Hygeia, M. de Gasparis announced another member of the asteroid family, which he named *Parthenope*, at the suggestion of Sir John Herschel, that name having formerly been given to the city of Naples.

Four months after the introduction to Parthenope, astronomers were made acquainted with the existence of *Clio*, or *Victoria*, as she is sometimes called. This planet was discovered by Mr. Hind, and is the twelfth in order of discovery.

Only about seven weeks elapsed after the discovery of the last-named planet, till another was announced by M. de Gasparis, of Naples. This newly-discovered body was named *Egeria*, by M. Le Verrier.

In May, 1851, Mr. Hind again proclaimed to the world the existence of a newly-discovered asteroid, which Sir John Herschel named *Irene*.

About two months after, *Eunomia* was recorded by its discoverer, De Gasparis, as belonging to the group of small planets. This is the fifteenth in order of discovery.

The sixteenth of the asteroidal group is called *Psyche*, and was also discovered by De Gasparis, of Naples, in the year 1852.

M. Luther, the director of the observatory at Bilk, announced the discovery of the seventeenth asteroid, in 1852, one month after the discovery of Psyche. It received the name of *Thetis*. The year 1852 is noted for the discovery of no less than eight new planets, four of which were discovered by Mr. Hind. In June of that year, he discovered the eighteenth asteroid called *Melpomene;* and in the same year, two months after, he discovered *Fortuna*, the nineteenth. On the 19th of September of the same year, M. de Gasparis discovered *Massilia*, the twentieth; and in the following November, M. Goldschmidt announced the discovery of *Lutetia*, the twenty-first asteroid. On the following day, November 16th, Mr. Hind discovered *Calliope*, the twenty-second; and in December of the same year, the same astronomer discovered *Thalia*, the twenty-third of the group.

In 1853, four new asteroids were added to the number already known—namely, *Themis*, the twenty-fourth, discovered by De Gasparis, April 5; and *Phocea*, the twenty-fifth, discovered by Chacornac on the following day, April 6. In May of that year, Luther discovered *Proserpina*, the twenty-sixth; and in November, Hind discovered the twenty-seventh, which is called *Euterpe*.

In the year 1854, six new planets were made known: the twenty-eighth, *Bel-*

lona, was discovered by Luther on the 1st of March; *Amphitrite*, the twenty-ninth, was discovered on the following day, March 2, by Marth; *Urania*, the thirtieth, by Hind, in July; *Euphrosyne*, the thirty-first, in September, by Ferguson, at the Washington Observatory; *Pomona*, the thirty-second, by Goldschmidt, on the 26th of October; and the thirty-third by Chacornac, on the 28th of the same month. This is called *Polymnia*.

M. Chacornac, of the Paris Observatory, discovered a new planet on the 6th of April, 1855, which was named *Circe*. It forms the thirty-fourth asteroid of the group. The thirty-fifth was detected by Dr. Luther, of Bilk, on the 19th of April of the same year, which was called *Leucothea*.

This group of small planets is situated between the planets of small mass, which rotate slowly, and the greater bodies of our system, whose diurnal revolution is performed in a much shorter time.

Whatever may be their origin, a subject on which astronomers differ so widely, they certainly are very dissimilar to the other components of the solar system. Their periods vary from a little more than three to five and a half years. Their orbits are all within a zone not exceeding one hundred millions of miles; and their diameters, although not satisfactorily ascertained, are not supposed to exceed three or four hundred miles at most. Some of them are believed to be even less than one hundred miles in diameter. The aggregate mass of these small bodies does not exceed, according to M. Le Verrier, the one-fourth of the mass of our Earth.

Sir John Herschel says: "A man placed on one of them would spring with ease 60 feet high, and sustain no greater shock in his descent than he does on the Earth from leaping a yard." This is owing to the force of gravity being so much less on these small bodies.

In reference to the theory of Dr. Olbers, Sir John Herschel remarks that "Whatever may be thought of such a speculation as a physical hypothesis, this conclusion has been verified to a considerable extent, as a matter of fact, by subsequent discovery."

Mr. Hind thus concludes his remarks upon the theory of Olbers: "We have already alluded to the near approximation of the orbits of the small planets at the points of mutual intersection; a circumstance which induced Olbers and many other astronomers to consider these bodies as the fragments of a large planet formerly revolving at about the same mean distance from the Sun, which had been shivered into pieces by some great internal explosion or an external shock. The idea of the German astronomer has been so strongly countenanced by the discoveries of the last five years, that we cannot fairly reject it, until another theory has been advanced which would account equally well for the peculiarities observed in the zone of planets, however unwilling we may be to admit the possibility of such tremendous catastrophes, and notwithstanding the great difference in the mean distances of Flora and Hygeia. Yet it may be found that these small bodies, so far from being portions of the wreck of a great planet, were created in their present state for some wise purpose, which the progress of astronomy in future ages may eventually unfold."

On the other hand, M. Le Verrier is of opinion that the eccentricities and inclinations of the orbits of the asteroids are entirely incompatible with the theory of Olbers; and supposing them to have had a common origin, the force required to launch the fragments of the larger planet into the orbits which they now occupy would be greater than we could, by any mathematical reasoning, be warranted in believing could ever have been exerted. His opinion is, therefore, that the asteroids are, and always have been, bodies smaller than the other planets; and that they revolve in orbits suited to the projectile force which they received from the hand of the Creator.

At a meeting of the "American Association for the Advancement of Science," which met at Providence, August, 1855, Professor S. Alexander communicated the results of his investigations on the probable origin of the asteroids. He considers it almost a certainty that in the space between Mars and Jupiter a planet once revolved, at about 268,000,000 of miles from the Sun, the equatorial diameter of which was about 70,000, and the polar diameter only about 8 miles. This body, therefore, was not a globe, but a *disc.* He supposed it to have been broken in fragments, owing to its velocity of rotation, as a grindstone will sometimes burst when driven furiously. As the outer parts of this disc necessarily moved faster than those near the centre, they must have been thrown into larger orbits than those which move more slowly. The fragments near the circumference would have a larger orbit than the parent planet, and those near the centre would move in smaller orbits than their original. To those which moved most rapidly, and which now occupy the larger orbits, the point of explosion would be their perihelion; while to those fragments which constituted the centre of the original planet, the place of explosion would be their aphelion, as their velocity would be diminishing. This theory of Professor Alexander is widely at variance with the views of many astronomers.

Bode's Law.

NOTE 15, PAGE 57.

BETWEEN the orbits of Mars and Jupiter, there occurs an interval of about 350,000,000 of miles, in which no planet was known to exist previous to the commencement of the nineteenth century.

Kepler, who lived about 300 years ago, first entertained the opinion that a planet existed between the orbits of the planets Mars and Jupiter. But owing to certain superstitious notions which he, among other scientific men of those times, entertained with regard to numbers, particularly to the number *seven,* he renounced this idea for a time, believing it to be erroneous. Among some of the reasons assigned for the relinquishment of this theory is, that there are *seven* openings in the head—namely, two ears, two eyes, two nostrils, and one mouth; and, also, that there are but seven tones in the gamut.

But as he was an observing philosopher, as well as a mathematician, he was forced to return to his former opinion; and in the first work which he ever published, he suggested that there must be a planet in the great void between Mars and Jupiter, or otherwise the harmony of the system would be broken. This

idea found favor in the German school, who, at a later period, embraced the theory, and resolved to test the truth of it. Their interest was aroused by the discovery of Uranus, by Sir William Herschel, in 1781. Although that planet was then the known boundary of our solar system, it served to account for certain disturbances in the motions of Jupiter and Saturn which had never been explained.

Professor Bode, of Berlin, embraced the opinion, first promulgated by Kepler, that an undiscovered body existed between the orbits of Mars and Jupiter, because as we recede from the Sun the distances of the planets form a geometrical series of which the common ratio is 2, as will be seen by the following table, (allowing the distance of the Earth to equal 10,) which, however, is a mere approximation to the truth, this theory not being considered by astronomers as sufficiently exact to deserve the name of a *law*:—

Mercury	$= 4 = 4$	Jupiter	$= 52 = 4 + (3 \times 2^4)$
Venus	$= 7 = 4 \times (3 \times 2^0)$	Saturn	$= 100 = 4 + (3 \times 2^5)$
Earth	$= 10 = 4 + (3 \times 2^1)$	Uranus	$= 196 = 4 + (3 \times 2^6)$
Mars	$= 16 = 4 + (3 \times 2^2)$	Neptune	$= 388 = 4 + (3 \times 2^7)$
Asteroids	$= 28 = 4 + (3 \times 2^3)$		

It will be seen, however, that this supposed law does not give the true distance for the planet Neptune.

Neptune.

Note 16, Page 64.

The circumstances which attended the discovery of the planet Neptune were of a very extraordinary character. Uranus had often been observed by Flamstead, Le Monnier, and others, prior to its discovery by Sir William Herschel, and was each time recorded as a fixed star. It was thought to be the utmost boundary of the solar system; and in order to ascertain its orbit, the most remote as well as modern observations were consulted. The first recorded notice of Uranus as a fixed star was in the year 1690; since then several places have been assigned to it, until the year 1781, when Sir William Herschel pronounced it to be a planet. From that time till the year 1820 its movements were narrowly and carefully watched. In 1821, M. Bouvard, of Paris, undertook to compare the entire series of observations, and from them to compute its place for any given time, and also to determine the exact nature of the ellipse in which it moves. But he found it impossible to reconcile the unlooked-for discrepancies which continually appeared, and to combine all the observations so as to form an elliptical orbit. He was therefore induced to reject the earlier observations as unworthy of reliance; and from the recent ones he traced out a path for Uranus, and noted the places in the heavens which he conceived the planet would occupy during the few following years.

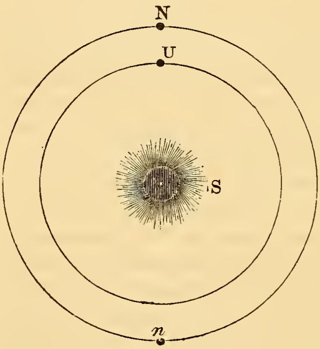
But fresh difficulties presented themselves; for the computed places of the planet did not coincide with the true places, and this variation appeared to be on the increase.

At this time, Dr. F. W. Bessel, a Prussian astronomer, publicly avowed that

either there must be another unknown planet which produced these perturbations, or the law of gravitation cannot be universal. Observers found, however, that up to the year 1830, the planet never appeared in its predicted place; for till then it was always in advance of Bouvard's calculation. It therefore became a matter of considerable interest to determine some plausible reason for this disagreement of theory and observation. It was strongly suspected that some unknown body might be attracting Uranus in some unascertained direction; and it was demonstrated that if the attraction of an unknown body caused the disturbance, that body must be situated somewhere beyond the orbit of Uranus; for otherwise its influence would have been perceptible in the movements of Saturn.

Two mathematicians in particular now devoted themselves to the task of attempting to find the situation of this disturbing body. These were M. Le Verrier, in France, and Mr. Adams, in England. M. Le Verrier sent his calculations to Dr. Galle, of Berlin, indicating the positions which the planet would occupy on certain given days. On the night following the day on which he received this communication—namely, the 23d of September, 1846—Dr. Galle pointed his telescope to the designated spot, within a degree of which he detected the looked-for planet, in consequence of its presenting a large planetary disc under high magnifying power. At that very time Professor Challis was searching for it in the same field, under the direction of Mr. Adams; and he subsequently found that he had really seen the planet seven weeks before Dr. Galle, and had entered its place twice in his list of observations.

Fig. 204.



A reference to *fig.* 204 will make it at once plain why Neptune's power to disturb Uranus was so much greater just previous to the period of its discovery than it had been during the preceding century. Let S represent the Sun, U Uranus moving in its orbit round the Sun, and N Neptune travelling in his orbit beyond. Uranus performs his journey round the Sun in his smaller orbit in 84 years, whereas Neptune requires 164 years to perform his orbitual revolution; consequently, if the planets started together from the positions U and N, after 84 years Uranus would be again at U, but Neptune would then be only half round his orbit at *n*, and therefore the two bodies would be widely asunder. After another 84 years, Uranus would be at U for the third time, and Neptune would again be at N, so that the two bodies would be once more comparatively near together. They were in this relation shortly before the year 1830; Uranus had recently passed between Neptune and the Sun, and all the time it had been approaching Neptune it was attracted forward by the influence of the latter. In 1830, Uranus had already got so far past Neptune that this latter body now influenced it by holding it back, rather than by attracting it forward; and consequently, in 1830, Uranus was again found to occupy the place indicated by the tables of M. Bouvard. Thus was the existence of this planet

predicted, and its elements assigned, from considerations purely theoretical, showing the utility of mathematical knowledge in the study of the universe.

After the discovery of Neptune, it became highly important to ascertain if any recorded observation of the planet could be found in the various catalogues of stars; for should it be discovered that this body had been included in any catalogue, and its place recorded as a fixed star, a comparison between that position and the place it occupies at present, noting the interval of time between the two observations, would afford means whereby to compute its rate of motion, its periodic time, and other particulars dependent on these elements.

After much research, it was found that this body had been observed and recorded twice by Lalande. With these data our late distinguished countryman, Mr. Sears C. Walker, at that time connected with the Washington Observatory, undertook the investigation of the orbit of the new planet. He found that the period assigned by Le Verrier and Adams was more than 50 years too great, and that it is 700,000,000 of miles nearer to the Sun than those astronomers had supposed. These elements, thus corrected by Mr. Walker, agree well with the calculations of Professor Peirce, and are considered by all astronomers as the most exact determination of the orbit of Neptune which has ever appeared.

From the planet Neptune our Earth cannot be visible, even with the best telescopes, as it must always be oscillating, as it were, so immediately in the vicinity of the Sun, as to be entirely invisible. Even our transits could not be seen at that distance, owing to the inferior magnitude of our planet.

Our Earth, as seen from the Moon.

Note 17, Page 67.

As our Earth is the primary centre of motion of the Moon, the lunar astronomer would at first be likely to suppose it stationary with regard to the other heavenly bodies, which to him appear to move slowly beside and behind it; his own habitation, the Moon, seeming to be at rest also.

Although the Earth would appear to occupy an almost fixed place in his firmament, its diurnal rotation would serve him as a perfect chronometer, no motion with which we are acquainted being so equable as that of the Earth on its axis. Our seas, mountains, plains, volcanoes, and regions of perpetual snow, by the contrast of their reflected light, producing various shades of color, would be successively brought into the view of an observer on the Moon by the rotation of the Earth on its axis.

An inhabitant of the Moon will never see the Earth, if he should live on that hemisphere which is unknown to us; therefore, in order to enjoy *moonlight*, he must travel round to that side of his globe which is always turned towards the Earth; for our Earth is a moon to the lunarians.

As the Moon possesses little or no atmosphere, the disappearance of the Sun is accompanied by the blackest night, except where the sunlight reflected from the Earth dispels the extreme darkness.

When the Moon is in opposition to the Sun, or *full*, the inhabitants of the Moon have *new* moon; for our Earth is then between them and the Sun, appearing first

like a fine crescent, increasing continually, till finally, at the time of our new moon, our Earth would be opposite to the Sun, and consequently shine upon them with a full orb. The Moon is then *new* to us, and the light which the Earth reflects back upon the Moon, when only a small crescent of her illuminated hemisphere is towards us, enables us to see the outline of the dark part of the Moon's disc. This reflected earthlight is called by the French *lumière cendrée;* and by the vulgar it is said to be the *old moon in the new moon's arms.*

The mean apparent diameter of the Moon, as seen from the Earth, is 31′ 7″; and the diameter of the Earth, as seen from the Moon, subtends an angle of 1° 54′. By squaring these two apparent diameters, we find the proportional difference between the surfaces is as 13 to 1, nearly. According to this calculation, the Earth appears 13 times larger to the inhabitants of the Moon than the Moon appears to us; and supposing our Earth to be as capable of reflecting light as the Moon, the lunarians must enjoy a moonlight thirteen times brighter than ours.

As the Moon revolves upon her axis in the same time she performs a synodic revolution, which is in about 29½ of our days, a day and night on the Moon must be equal to 29½ days on the Earth. During this long continuance of sunlight, which would equal 15 times 24 hours, or half a lunar day, the heat would be excessive; and the absence of the Sun for as many successive hours would render the temperature below freezing. Thus each lunar day is an oppressive summer, and each night a rigorous winter. In one of our years the Sun rises and sets to the inhabitants of the Moon only about thirteen times.

To an inhabitant of the middle of that hemisphere of the Moon which is turned towards us, the Earth will always appear on or near his meridian; at the time of sunrise to him, the Earth will present half of her illuminated disc, the other half will be visible at his sunset. At his midnight the Earth will be *full*, giving as much light as thirteen full moons.

Heat of Moonlight.

NOTE 18, PAGE 77.

THAT hemisphere of the Moon towards the Earth must necessarily be very much heated; yet, until recently, no effect has been perceived by the most delicate instruments. And although a slight increase of temperature may have been detected by some, the fact is not considered to be proved beyond a doubt.

Lunar light was experimented on with a large burning-glass by the younger De la Hire, a French astronomer, at a time when the Moon was full and on the meridian. No sensible increase of heat could be discovered; although the Moon's rays were concentrated so as to fill only the three-hundredth part of the space they naturally occupy, thereby possessing the power of three hundred full moons, yet no perceptible heat could be detected.

Forbes, in the transactions of the Royal Society of Edinburgh, vol. xiii., gives it as his opinion, after many experiments, that moonlight is devoid of heat sufficient to be detected by the most delicate instruments known to us.

Sir John Herschel is of opinion that the Moon's rays may possess heat, but that it may be absorbed in the upper regions of our atmosphere, which he thinks

"the tendency to disappearance of clouds under the full moon" serves as a proof. But, on the other hand, Professor Loomis, in a paper read before the American Association, at Cleveland, Ohio, furnishes a table founded on the meteorological observations recorded at the Greenwich Observatory, which serves to show that the Moon exerts no influence whatever on our atmosphere, and that our sky is as cloudy at *full* moon as at *new*.

Observations have also been made at various times at Padua, Vienna, London, Munich, &c., by Toaldo, Pilgrim, Horsley, and Schübler, the results of which tend to confirm the opinion that the Moon has no influence over our weather, which would undoubtedly be the case could any heat be detected in moonlight.

The ancients attributed changes of weather to the Moon; for we find the opinion entertained by some of the Greek writers, who no doubt received it, with their general notions of physics, from the nations of the East. They also believed not only the Sun, but some of the fixed stars, to have an influence on the weather. Pliny, a philosopher who lived in the first century of the Christian era, quotes Varro, (a Roman statesman and philosopher, who was born B. C. 116, and was the most learned man of his age,) who says: "If the upper horn of the Moon be obscure, the decline of the Moon will bring rain; if the lower horn be indistinct, the rain will happen before full moon; but rain may be expected at the time of full moon if the blackness be in the middle."—*Plin. Nat. Hist.* lib. xviii. cap. 35.

Virgil makes the prognostic of the fourth day of the Moon decisive for the whole lunation.—*Georgic*, lib. i. lin. 143.

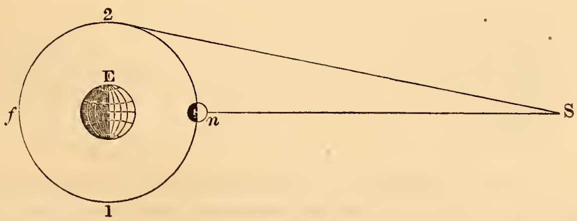
In a letter to M. Arago, in the "*Comptes Rendus*," Melloni states that he has succeeded in detecting a raised temperature in moonlight, which had been condensed by means of a lens three feet in diameter. Professor Mosotti-Lavagna, of the University of Pisa, and Professor Belli, of the University of Pavia, witnessed these experiments of Melloni, which they considered satisfactory proof of the heat of moonlight. The amount of the deviations of temperature accorded with the age of the Moon and her altitude at the time of each observation.

From the foregoing statements on both sides of the question, it will be seen that philosophers are still in doubt as to the heat of moonlight.

Irregularities of the Moon's Motions.

NOTE 19, PAGE 78.

Fig. 205.



Let S (*fig.* 205) be the position of the Sun, E the position of the Earth, and *n* the Moon travelling round the Earth in its orbit. It will be evident that when

the Moon is at n the Sun attracts it more strongly than it does the Earth; hence, at new moon the Sun's influence draws it away from the Earth. When the Moon is at f, the Sun attracts the Earth more strongly than the Moon; thus at full moon the Sun's influence tends again to increase the distance between the Earth and Moon. When the Moon is at 2, the Sun attracts the Moon in the direction S 2, but attracts the Earth in the line S n; a similar action takes place when the Moon is at 1. Hence, towards the quarters of the Moon the Sun's influence brings the Earth and Moon continually a little nearer together than they would be without it; for if two bodies move along two sides of a triangle towards its apex, they must necessarily approach each other.

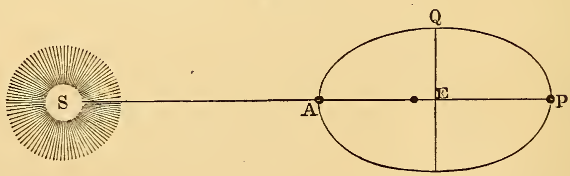
Again, when the Moon is moving from 1 to n, its motion is quickened by the Sun's attraction, because its path lies somewhat towards that body; but when it is moving from n to 2, its velocity is retarded by the Sun's influence, because its path is receding from him.

Among the numerous inequalities to which the Moon's motions are liable, the most prominent are the Equation of the Centre, the Evection, the Variation, and the Annual Equation.

The *Equation of the Centre* is the difference between the Moon's true and mean longitude, which vanishes at the apsides or extremities of the major axis, and attains its maximum at 90° distant from these points, or at the quadratures, where it is equal to the eccentricity of the orbit. The Equation of the Centre is equal to the angle formed at the planet, and subtended by the eccentricity of its orbit.

The *Evection* is a variation in the equation of the centre depending on the position of the apsides of the lunar orbit. It was discovered in the first century by Ptolemy, but it remained for Newton to explain its true cause. When the lunar apsides are in syzigies, the action of the Sun increases the eccentricity of the Moon's orbit, or the equation of the centre. If the Moon be between the Earth and the Sun, or directly opposite to him, her distance from the Earth would be increased; thus, at new moon the Sun attracts the Moon more than the Earth, and at full moon he attracts the Earth more than the Moon; in either case augmenting the Moon's distance from the Earth, and increasing the eccentricity, or equation of the centre. This increase is the evection, which may be more fully explained by the following figure.

Fig. 206.

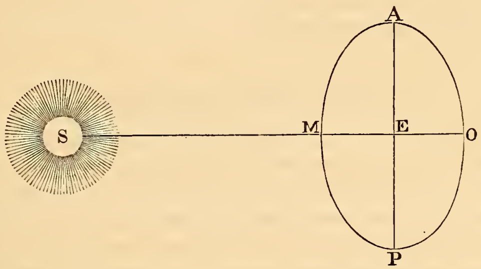


If the Moon be in conjunction, as at A, the Sun attracts her from the Earth E; and if the Moon be at the point P, he attracts the Earth more than the Moon; consequently, the lunar orbit is rendered more elliptical, which increases the equation of the centre. The Moon's gravitation to the Earth is at its maximum

when the Moon is 90° from the Sun, or in quadratures, which tends to diminish the distance Q E.

If the line of apsides be at right angles to the radius vector of the Earth, the attraction of the Sun increases the distance of the Moon from the Earth, by which means it diminishes the eccentricity of the Moon's orbit, and causes it to approach nearer to a circle. If the Moon be in quadratures, the increase in her gravitation lessens her distance from the Earth, which also diminishes the eccentricity, and thereby the equation of the centre.

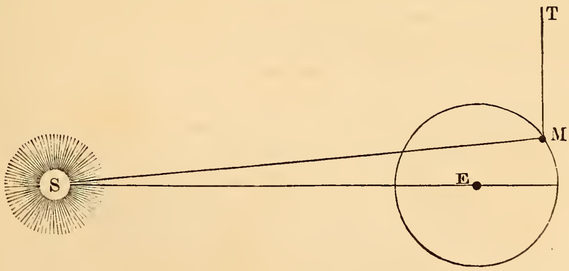
Fig. 207.



Let A P be the line of apsides, and S E the radius vector of the Earth; when the Moon is at M or O, the attraction of the Sun tends to increase the distance of the Moon from the Earth, and consequently to bring the lunar orbit more nearly to a circle. The force of gravity when the Moon is at A or P in quadratures would have the same tendency; that is, to render the lunar orbit less elliptical, and consequently to diminish the equation of the centre. This diminution is the *evection.*

The *Variation* is an inequality in the Moon's longitude, by which the Moon's velocity is accelerated, but at an unequal rate; its maximum happening in the octants, or midway between the quadratures and syzigies, the acceleration being zero at the quadratures and conjunctions.

Fig. 208.



The Sun's force, acting on the Moon in the direction S M, may be resolved into two other forces—one in the direction M E, which produces the evection, the other in the direction M T, tangent to the Moon's orbit. This tangential force produces the variation, by accelerating the Moon's velocity.

Variation was discovered by Tycho Brahé, but was explained by Newton.

The fourth lunar inequality is the *Annual Equation*, which arises from a variation in the distance of the Earth from the Sun, and is consequently owing to the eccentricity of the terrestrial orbit. When the Earth is in perihelion, the action of the Sun is greatest, which thereby dilates the lunar orbit, so that the angular motion of the Moon is diminished; but as the Earth approaches aphelion, her orbit contracts, and the Moon's angular motion is accelerated.

Annual Equation was discovered by Tycho Brahé, by computing the places of the Moon for the various seasons of the year. He thus observed the real motion to be slower than the mean motion for six months from perihelion to aphelion, and faster during the other six months.

Has the Moon an Atmosphere?

Note 20, Page 78.

Whenever the light of the heavenly bodies passes through a dense atmosphere, they do not appear in their true places; on this account, the Sun is seen from the Earth's surface when he is really below the horizon. If the Moon had an atmosphere of any appreciable density, the apparent position of a star would be changed during an occultation, so long as it was viewed through the denser medium. In other words, the star would be visible through the Moon's atmosphere when it was really behind the Moon, just as the Sun is seen through the Earth's atmosphere when he is below the horizon; in that case, the star would be concealed a shorter time than it ought to be by a body of the size of the Moon.

If the Moon had an atmosphere possessing only the 1980th part of the density of the Earth's atmosphere, this influence would be discernible; but no such result takes place, and therefore it is known that the Moon has not an atmosphere of even this trifling density. If our satellite is devoid of this gaseous envelope, the heavenly bodies must appear to be placed on a perfectly black background; there could be no vapors nor rain, clouds nor air, and consequently no sound; neither animal nor vegetable life, such as is common to our Earth, can exist there; naught but a barren and voiceless wilderness, subject to the extremes of heat and cold. But these are only our suppositions; He who created the lunar orb has fitted it as an agreeable abode for the intelligences he may have been pleased to place there.

In June, 1831, Captain Smyth observed, under peculiarly favorable circumstances, a passage of the Moon over the planet Jupiter. The illuminated half of the Moon first passed over the planet, and then the dark half; so that the planet was seen to emerge from behind the unilluminated part of the Moon's disc. As the planet appeared from behind the Moon it was singularly distinct and clear, the markings on its surface were evenly and boldly cut by the Moon's body; neither its color nor the brilliancy of its light were in any way affected. From these observations, Captain Smyth concluded that the Moon cannot have an atmosphere of any appreciable density.

In the dark part of the new moon a luminous spot has been frequently observed by Cassini, Sir William Herschel, Captain Kater, and Baily. In 1794, the same phenomenon was seen by two persons with the naked eye. This luminous appear-

ance is described by Dr. Maskelyne in vol. lxxxiv. of the Philosophical Transactions. It appears in the vicinity of the mountain known as Aristarchus, the outline of which may be distinctly seen, although not illuminated by the Sun's rays. In the centre of this mountain a bright spot resembling a star of the ninth or tenth magnitude may sometimes be seen for several seconds, shining quite brilliantly. Should this light result from the action of volcanoes, there would be no longer a doubt that the Moon is surrounded by an atmosphere, for fire cannot be maintained without air. Smyth, in his Celestial Cycle, vol. i. p. 133, says: "I have myself occasionally, though rarely, observed both a diminution of a star's brightness and an apparent projection of a star upon the Moon's disc at the instant of contact." These facts serve as proofs of the existence of a lunar atmosphere, yet the question is an unsettled one; but if our satellite is surrounded by an atmosphere, it must be of a nature totally different from our own.

At a meeting of the American Association for the Advancement of Science, held at Providence, R. I., August, 1855, there was a diversity of opinion with regard to a lunar atmosphere. Dr. B. A. Gould, Jr., called attention to observations made by himself and Professor Winlock, tending to establish the existence of a *twilight* at the Moon. This phenomenon was particularly observed at the time of *new moon.* The twilight appeared to be distinctly defined; its breadth, however, did not measure more than two seconds.

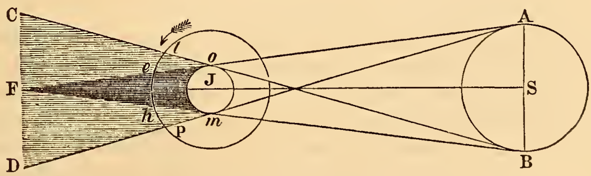
Eclipses of Jupiter's Satellites.

Note 21, Page 89.

Early in the seventeenth century the important discovery of the system of Jupiter furnished an undeniable proof of the truth of the Copernican theory, and afforded satisfactory evidence of the principle of universal gravitation.

The eclipses of Jupiter's satellites are of frequent occurrence, and may be seen by means of telescopes of very moderate power. The shadow of the enormous sphere of that planet extends out into space more than half the distance of the Sun from the Earth; that is, about 56,000,000 of miles. The three nearest satellites suffer eclipse every time they pass behind the planet; the fourth sometimes escapes eclipse, because, like our Moon, its orbit is inclined to the orbit of its primary, so that its path at times lies above or below the edge of the shadow.

Fig. 209.



In the figure let S represent the centre of the Sun and J the planet Jupiter. The cone *o* F *m* will represent the shadow of Jupiter, and the spaces C *o* F and

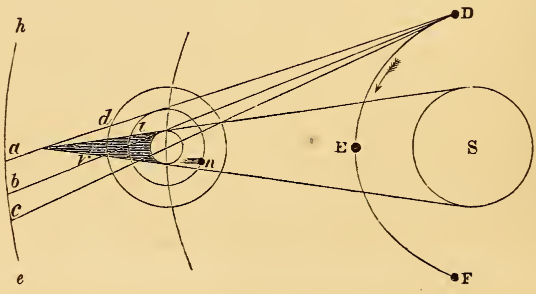
F *m* D will be the penumbra, from which a part of the Sun's light will be excluded. Thus it is very difficult to note the *precise* time of the disappearance of a satellite, as it partially disappears before it actually enters the shadow, its light being much obscured by the penumbra. Hence it will be seen that the disc of a satellite may become invisible to us before it is totally eclipsed. The brilliancy of the planet itself also prevents us from detecting the immersion with precision.

In the foregoing figure, *e h* represents the portion of its orbit which a satellite must describe while passing through the planet's shadow, and *l p* the section of its orbit which lies in the penumbra.

When the satellite is moving from west to east, or in the direction of the arrow with regard to an observer on the Earth, it is liable to eclipse; but when it appears to be moving from east to west, it is then seen to transit the planet's disc like a bead of light; while on other occasions the satellites have been observed as dark spots; which is a very singular phenomenon, when we consider that their illuminated hemispheres are then turned towards us. The only solution of this difficulty seems to be that some of the satellites are known to vary in brilliancy, owing, it is supposed, to spots on their surfaces less adapted for reflecting light than the other portions of their discs.

Before opposition, the immersions of the satellites into the planet's shadow are visible, the emersions being usually hidden by the body of the planet.

Fig. 210.



In the above figure let S be the Sun and D E F an arc of the Earth's orbit; *h e* a portion of the concave sphere of the heavens, between which and the orbit of the Earth is the planet Jupiter, casting his conical shadow opposite to the Sun. Let the Earth be supposed to be in that part of her orbit designated by D, and moving in the direction D E, or from west to east. Let *l n* be the orbit of the first satellite. Now, as the planet Jupiter would not be in opposition until the Earth would be between him and the Sun, as at E, the point D must be a situation of the Earth *before* opposition. In that case, as before stated, the immersions are seen; for

the ray D *l* would cause the satellite to be projected on the surface of the heavens *h e* at *b*, and the planet Jupiter would appear to be among the stars at *c*. Therefore, the emersion would take place when the satellite was behind the planet, and therefore invisible to the observer at D.

But let *d* represent the orbit of the third satellite. If the Earth were at D, the immersion at *d* would be visible, as well as the emersion at *o*; so that the immersion and emersion would appear on the same side of the planet, after which the satellite would again be eclipsed by passing behind the body of the planet. For when the immersion happens, we see the satellite among the stars at *a*, and at the moment of emersion at *b*, after which it disappears a second time behind the planet's body.

After opposition, or when the Earth is at F, the emersions of the satellites are visible, and the immersions invisible, being generally hidden by the body of the planet. When the Earth is at E, between the Sun and Jupiter, which is the place of opposition, the immersions and emersions are both invisible, because they occur immediately behind the body of the planet. The same is the case when the Earth is in superior conjunction, or in that part of its orbit opposite to E.

When a satellite passes between the Earth and its primary, its small shadow may be seen traversing the planet's disc, causing to the inhabitants of those localities the phenomena of solar eclipses just as the shadow of the Moon eclipses the Sun when passing over the terrestrial surface.

Before opposition, when the Earth is at D, the shadow of the satellite *precedes* the satellite itself. Thus, the shadow of the satellite at *n* falls on the planet and is visible from the point D *before* the body of the satellite arrives at a point between D and Jupiter. The contrary is the case *after* opposition, or when the Earth is at F. The eclipse of one of Jupiter's satellites is visible at the same moment at every point of the Earth's hemisphere which is turned towards it; consequently, if these eclipses be accurately noted and compared with the times computed for their appearance for Washington, Greenwich, or any other meridian, they would serve to find the longitude of the observer; for if the difference of time between the meridians of Washington or Greenwich and that of the observer should be found to be *one hour*, the difference of longitude must be 15°. This method of obtaining longitude is not available at sea, and is, besides, not the most accurate, though it may be relied on to within a quarter of a degree.

The Rings of Saturn, their Nature and Constitution.

Note 22, Page 90.

When Galileo first saw Saturn through his telescope, he thought the planet was oblong; but on further examination he was led to believe that it was composed of *three* globes—a large one in the centre, and a small one on each side of it. But it was not long before it was discovered that what he considered as two small globes were not really such, but that the globe of the planet was distinctly visible, having two projections, which he termed *ansæ*, from their resemblance to *handles*.

These observations were made known to Kepler about the year 1610; but it was

not till fifty years after, that Hevelius turned his attention towards the planet Saturn, and confirmed Galileo's observations.

In 1659, Huyghens proclaimed to the world the discovery of Saturn's ring, in a work entitled *Systema Saturnium.*

In the year 1665, the Messrs. Ball, of Minehead, England, saw the dark elliptical line which divides the ring into two parts; and Whiston informs us that a fixed star was seen between the ring and the body of the planet.

About the year 1675, Dominic Cassini, astronomer at the Paris Observatory, discovered that, instead of one, the planet was encircled by two luminous rings. In 1787, La Place, with his usual sagacity, says, in his "Theory of Saturn's Ring," that "it must be formed of *several rings* having nearly the same plane." This theory of La Place was very soon verified; for in 1791, Sir William Herschel communicated to the Royal Society of London the result of his observations in June, 1780, which was that he had discovered a second dark line upon the inner side of Saturn's ring, and on the preceding arm only, showing that it must be divided into three parts. This second line, however, soon vanished, which led astronomers to suppose the opening between the rings to be very narrow, and the rings eccentric. James Cassini accounted for the appearance and disappearance of the sides of the rings happening at irregular intervals to the annular surface not being in the same plane.

Messier was of opinion, from certain inequalities of light, some parts appearing more luminous than the rest, that the surface of the rings must have fixed inequalities, and those, too, of grand proportions, to be distinguished at such an immense distance, even with a good telescope. This irregularity of surface La Place adduces as necessary for the preservation of the equilibrium of the ring. He says: "I will add that these inequalities are necessary to maintain the equilibrium of the ring; for if it were perfectly alike in all its parts, its equilibrium would be deranged by the slightest force, such as the attraction of a comet or a satellite, and thus the ring would be destroyed by being precipitated on the surface of the planet." La Place also considered it as necessary, in order to preserve the equilibrium of the ring, that its particles should not have a tendency to separate from it,—a condition only to be fulfilled by a rapid rotary motion round its centre of gravity and in its own plane.

Mr. G. P. Bond, in a paper published in the American Astronomical Journal, of May, 1851, states, as his opinion, that the subdivisions of Saturn's ring are not *permanent*, from the fact that the division near the inner edge, observed by Sir William Herschel on four different nights, in June, 1780, was never seen by him before that period or afterwards, although he devoted much time during thirty years to observations on the system of Saturn.

In Gruithuisen's *Astron. Jahrbuch*, for 1840, mention is made of lines having been seen on both rings in 1813–14. Quételet, at Paris, and subsequently Captain Kater, have observed divisions in the outer ring of the planet. The latter-named gentleman saw *three* divisions in the outer ring in 1826, an account of which, together with full illustrations, may be found in vol. iv. part ii. of the Memoirs of the Astronomical Society. Professor Encke, at Berlin, in April and May, 1837, observed the outer ring nearly equally divided by a dark line. These

observations were published in the *Astronomische Nachrichten*, No. 338. De Vico, at Rome, Messrs. Lassell and Dawes, at Starfield, and others, also corroborate the foregoing testimony as to the subdivisions of Saturn's rings.

It is true that neither Struve, Bessel, Sir John Herschel, and some others whose instruments are of a superior order, have ever seen more than one division in the ring. The subdivisions are not usually visible in both rings at the same time, which Mr. Bond conjectures is owing to some real alterations in the disposition of the material of the rings. Hence he infers they are not solid, but composed of matter in a fluid state, which, within certain limits, changes their form and position in obedience to the laws of equilibrium of rotating bodies. So that should any disturbances bring the rings together, the velocities at the point of contact being nearly equal, they would coalesce without disastrous consequences.

Professor Peirce, in an ably-written paper published in the American Astronomical Journal, of June 16, 1851, sustains the above opinion of Mr. Bond. He says that Mr. Bond chiefly derived his argument for the fluidity of Saturn's ring from direct observation; whereas he demonstrates that it cannot be solid from purely mathematical considerations. His words are—"I maintain unconditionally, that *there is no conceivable form of irregularity, and no combination of irregularities consistent with an actual ring, which would serve to retain it about the primary if it were solid.*"

One proof of the fluidity of the rings is, that although the diameter of the outer part of the ring has not been observed to change, the inner edge is contracting gradually. The measurement of the inner edge, according to Huyghens, in 1657, was $6''{\cdot}5$. In 1695, Huyghens and Cassini found it to be $6''$ Bradley, in 1720, made $5''{\cdot}4$; and in 1799, Herschel's measurement was $5''$. According to the elder Struve, it was $4''{\cdot}36$ in 1826; in 1838, $4''{\cdot}04$, as measured by Encke and Galle; and in 1851 it only measured $3''{\cdot}67$, according to Otto Struve.

Professor Peirce, judging from these data, concludes that the breadth of the ring is decreasing more rapidly than formerly, and that in about 80 years hence the ring will be ruptured. The planet acts no part, he thinks, in maintaining the equilibrium of the ring, but that the satellites are the agents which sustain its position.

From the above it may be seen that the opinions of some of our greatest American astronomers are favorable to the fluidity of Saturn's rings. Their density is supposed to be nearly that of water.

In the introductory lecture to the course on Mechanical Science, delivered at the School of Mines, London, session 1851–52, Mr. Robert Hunt, Keeper of Mining Records, relates the following experiment,* illustrating the condition of bodies relieved from the influence of gravitation, which tends to prove that the remarkable phenomenon of luminous rings is due to the influence of motion exerted under peculiar conditions: If oil be dropped upon water, it swims; if upon alcohol, it sinks; but if we make a careful combination of water and alcohol, we obtain a fluid of the same specific gravity as the oil, and the globule of oil will swim in the very centre of the fluid, a perfect sphere. If into a properly-arranged glass box we pass a fine wire through the sphere of oil, and by means of a handle

* This experiment was first made by M. J. Plateau, and published in Annales de Chimie et de Physique, tome xxx. p. 203, and Mémoires de l'Academie de Bruxelles, tomes xvi. et xxiii.

cause the globule to revolve slowly, the sphere becomes an oblate spheroid: by increasing the motion, we flatten it still more, until at a certain rate of revolution it becomes a disc, when a ring of oil is thrown off from the central globule, and although separated by intervening water, it revolves at precisely the same rate. It is highly interesting to find mechanical science lending its aid in explaining the grander phenomena of the creation.—*Records of the School of Mines*, vol. i. p. 71.

There is some reason to suppose that the phenomenon of Saturn's ring was known in remote ages. In the "Indian Antiquities," by Maurice, is an engraving of *Sani*, the Saturn of the Hindus, taken from an image in a very ancient pagoda, which represents the deity encompassed by a ring formed of two serpents.

The Dark Ring of Saturn.

NOTE 23, PAGE 90.

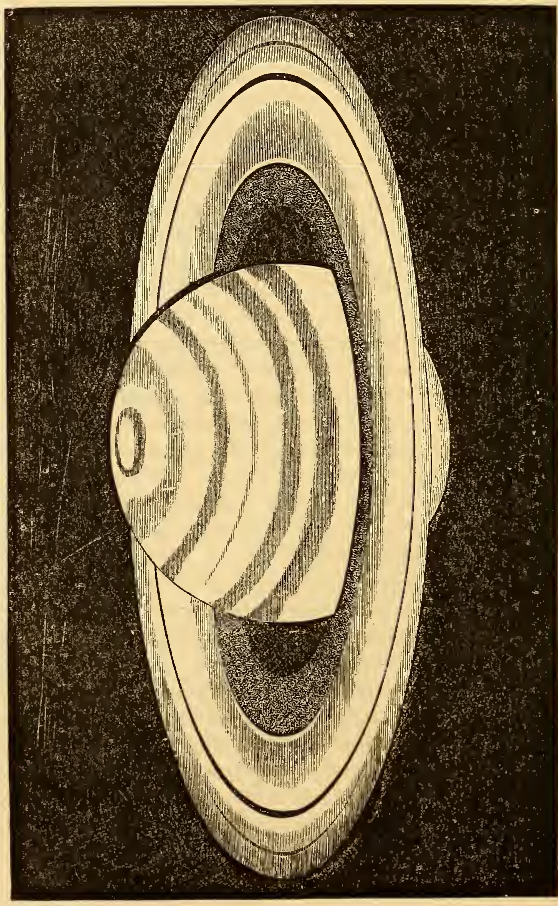


Fig. 211.

In 1838, Dr. Galle, of the Berlin Observatory, noticed a gradual shading of the inner ring of Saturn towards the body of the planet. But it was not until 1850 that the Messrs. Bond, of the Cambridge (Massachusetts) Observatory, succeeded in establishing the existence of a dark ring round the planet Saturn, a fact which hitherto had been only a matter of conjecture. It is not, as some have supposed, a subdivision of the luminous rings; for, unlike them, the light reflected from its surface is so feeble as to cause it to appear like a dark line across the planet's disc. The Rev. W. R. Dawes observed this dusky ring divided by a very narrow, darker line.

Mr. Lassell made some observations of the rings of Saturn in the years 1852–53, during a sojourn in the island of Malta. He described the interior, or dark ring, as well defined against the sky, the shadow of the ball of the planet being distinctly visible on it, although it was sufficiently transparent to permit the limbs of the planet to be seen through it. Mr. Lassell compares the appearance of that part of the dark ring which crosses the planet to that of a "crape veil." He therefore infers that its texture is of a semi-transparent nature, imperfectly transmitting the color or shade of the ground on which it is placed. The belts on the planet appeared of a dull, ruddy color, gradually shading into a greenish hue.*

A remarkable feature of the dark ring was its *transparency*, the part crossing the ball being decidedly lighter in shade than the other parts; the preceding and following limbs being distinctly visible, affording an indication of want of solidity, and corresponding to the requisitions of fluid matter.

Satellites of Saturn.

Note 24, Page 92.

On the 25th of March, 1655, Huyghens discovered a small star at the distance of about 3′ from the planet Saturn, and on the west side of it. The telescope which he used on that occasion was 12 feet focal length, which he had constructed himself. The ring of Saturn was in the position to appear like a luminous line extending on opposite sides of the planet. Having noted the situation of this small body, he found on the following evening that from its position it must be a satellite. He computed its period to be nearly 16 days. This first-discovered satellite is the sixth in order from the planet, and is called *Titan.*

When Huyghens made this discovery known, he announced this theory; viz. that as the number of planets and satellites was now equal, and as the aggregate of both amounted to 12, which was universally admitted to be a perfect number, that the planetary system was complete, and thus ventured to predict that no more satellites would be discovered.

In 1671, while the elder Cassini was examining the planet Saturn with a telescope of 17 feet focal length, he perceived a small star, which proved to be a satellite. This was Japetus, the eighth satellite in order from the planet, and the most distant from it. At its maximum brightness, Japetus appears like a star of the ninth magnitude. This satellite is only visible to us during that half of its revo-

* Memoirs of Royal Ast. Soc. vol. xxi. part i. p. 151.

lution when it is west of the planet; and as the same phenomenon always occurs when it is in that part of its orbit, astronomers have concluded that, like our Moon, it revolves on its axis in the same time it revolves around its primary. The variations of brightness are supposed to be owing to some parts of its surface being less capable of reflecting light than others.

The next satellite in order of discovery was *Rhea*, the fifth in order from the planet. Cassini, while searching for Japetus, which had become invisible, detected, with the aid of telescopes of 35 and 70 feet focal length, another satellite on the 23d of December, 1672.

In March, 1684, Cassini, through his untiring perseverance and unwearied observations, was rewarded by discovering *Dione*, the fourth satellite in order from the planet.

In the same month, and nearly about the same time, he discovered Tethys, the third satellite in order from the planet. These two last-named satellites were detected by Cassini with object-glasses of 100 and 136 feet focal length, constructed at Rome by Campini. Before the effects of chromatic aberration were obviated, it was found necessary to construct refracting telescopes of enormous length, which rendered them wholly unmanageable. Cassini and Huyghens simultaneously contrived means to obviate the difficulty by fixing the object-glass in a suitable position for observing a celestial body, and dispensing with the tube of the telescope altogether.

The second satellite from the planet, called Enceladus, was first seen by Sir William Herschel in August, 1787, but was not certainly ascertained to be a satellite till August, 1789, after the completion of his great 40-feet reflector. As soon as this noble instrument was directed to the planet Saturn, *six* satellites were immediately visible, one of which proved to be Enceladus. This satellite can be detected only by means of the most powerful telescopes.

In the following month, September, 1789, Sir William Herschel discovered the first satellite in order from the planet. This attendent moon is known by the name of *Mimas*. It can only be distinguished by means of the most powerful instruments. Sir William Herschel described it as a "very small lucid point." On account of its vicinity to the planet, this satellite is often invisible throughout the greater part of each revolution.

During a period of 59 years the planet Saturn was supposed to have only seven satellites. But on the 16th of September, 1848, Professor Bond, with the aid of the great Cambridge (Massachusetts) Refractor, discovered an eighth attendant on Saturn. This satellite, which is called Hyperion, was seen three nights after by Mr. Lassell, of Liverpool; that is, on the 19th of the same month. This newly-discovered satellite is the seventh in order from the planet.

The satellites of Saturn nearly all revolve in orbits that lie in the same general plane as the ring; therefore, when the ring is situated obliquely with regard to the Earth, so that its upper or under surface is towards us, the satellites appear to be scattered confusedly around the primary instead of moving across in straight lines, as Jupiter's moons. But when the edge of the ring is turned towards the Earth, the moons seem to move in straight lines. The innermost of them has been seen by Sir William Herschel travelling along the edge of the ring, like a bead

of light moving on a string. Very powerful telescopes enable observers to witness the eclipses of Saturn's moons.

In the year 1789, Sir William Herschel observed the *shadow* of Titan, the sixth satellite, transit Saturn's disc like a black spot.

Distance of the Sun in Winter and Summer.

NOTE 25, PAGE 107.

WE are farther from the Sun in June than in December; first, because the Earth requires a longer time to move from the vernal to the autumnal equinox than from the autumnal to the vernal, causing our spring and summer to be nearly eight days longer than our autumn and winter. The reason why the Earth is longer in performing her journey from March, the time of the vernal equinox, to September, the time of the autumnal equinox, than from September to March, is, that from the vernal equinox the Earth is continually receding farther from the Sun, and therefore his attractive power is constantly diminishing, thereby decreasing the velocity of her motion until she arrives at aphelion, or the farthest point from him.

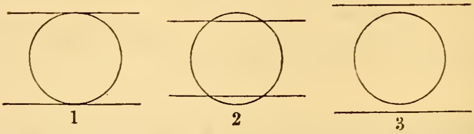
On account of the eccentricity of the Earth's elliptical orbit, any line (except the transverse axis) passing through the centre of the Sun must necessarily divide it into two unequal parts; and by the laws of elliptical motion the Earth moves through these two unequal portions with unequal velocities. As the perihelion always lies in the smaller portion, there the Earth's motion is most rapid.

As it requires 20,984 years for the Earth's perihelion to make one complete revolution, (in which time it will successively occupy every point of the ecliptic,) it follows that in half that time, or in 10,492 years, the spring and summer in the southern hemisphere, which is now shorter, will then be longer than the autumn and winter, corresponding with the present length of our seasons in the northern hemisphere.

Sir John Herschel has shown that the change in the perihelion can have no influence whatever on the temperature of the different portions of our globe; for although the Earth is nearer to the Sun while moving through that part of her orbit in which the perihelion lies than in the other part, and consequently receives a greater share of heat, yet as it moves faster, it is exposed to the heat for a shorter time. In the other part of her orbit, on the contrary, the Earth receives fewer of the Sun's rays, but as its motion is slower, it is exposed to them for a longer time.

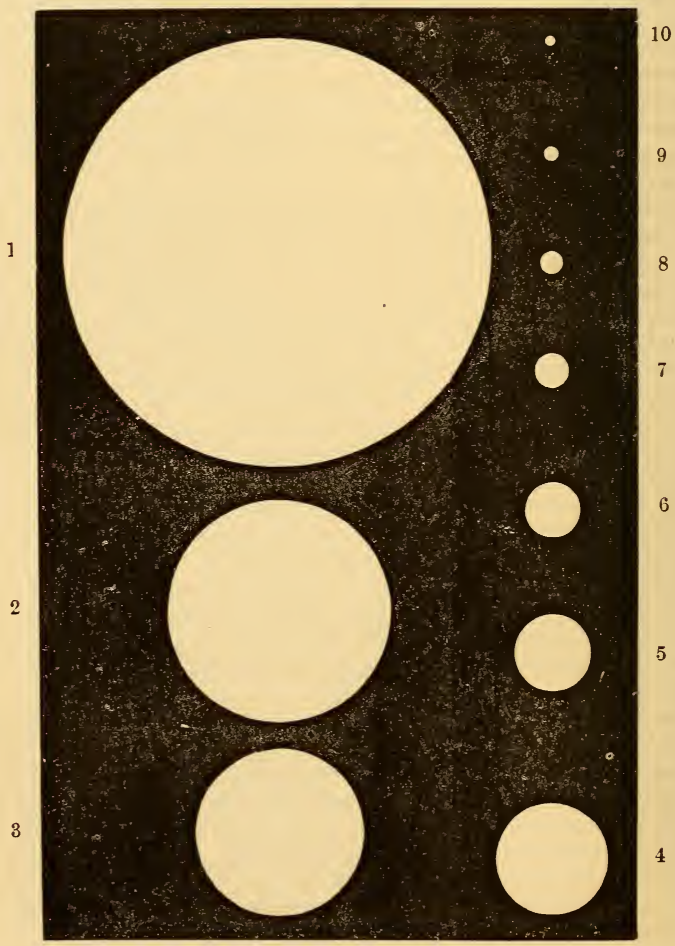
The Sun's apparent diameter being greater in winter than in summer, is another proof of his distance from us being greater in summer. This fact is clearly proved by means of a micrometer. This is an instrument across which are extended very fine threads or wires, so adjusted as to be exactly parallel to each other, and movable by means of a screw, so that they can be drawn close together or separated at pleasure, always, however, preserving their parallelism. When this instrument is attached to the telescope, the disc of the Sun may be accurately measured by causing the wires to touch the one the upper and the other the lower limb of the disc.

Fig. 212.



Now if the wires be adjusted so as to apparently touch each limb of the Sun on the 21st of December, as represented at 1, (*fig.* 212,) it will be found that by the 21st of June they will be beyond the edge of the Sun's disc, as at 3, (*fig.* 212.)

Fig. 213.



If they are made to touch on the 21st of June, by December they will be found to be within the boundary of the Sun's disc, as at 2, (*fig.* 212;) thus showing conclusively that the Sun's apparent diameter is greater in winter than in summer, which is owing to the difference of his distance from us in those seasons.

In *fig.* 213, if No. 1 be the apparent size of the Sun as seen from the planet Mercury, he would appear the size of No. 2 at Venus; 3, at the distance of the Earth; 4, at Mars; 5, at the nearest of the asteroids; 6, at the most distant asteroid; 7, at Jupiter; 8, at Saturn; 9, at Uranus; and 10, at the planet Neptune.

Day, as kept by Different Nations.

Note 26, Page 110.

Different nations begin their day at a different hour; thus, the Egyptians began their day at midnight, and from them Hipparchus introduced that mode of reckoning into astronomy. But at present astronomers count their day from noon to noon, and not twice 12 hours, according to the vulgar computation.

The method of beginning the civil day at midnight prevails in the United States, Great Britain, France, and indeed nearly throughout Europe. The Babylonians began their day at sunrise, from whence the hours calculated in this way are called Babylonic hours. In some parts of Germany and Italy they begin their day at sunset, and reckon twenty-four hours till it sets next day, calling that the 24th hour: these are generally termed Italian hours.

The Jews began their day at sunset, and divided it into twice 12 hours, as we do; but they reckoned 12 hours for the period of sunshine, be it long or short, and 12 hours for the period of darkness; so that their hours were continually varying in length, corresponding to the varying length of the days. The Romans also reckoned their hours after this manner. These hours were sometimes called planetary hours, because the five planets then known—namely, Jupiter, Saturn, Venus, Mars, and Mercury, together with the Sun and Moon—were regarded as presiding over the affairs of this world, and to take it by turns in the following order: First, Saturn, then Jupiter, Mars, the Sun, Venus, Mercury, and, lastly, the Moon. Each day of the week was named for that planet whose turn it was to preside the first hour. Thus, assigning the first hour of Saturday to Saturn, the second hour of that day would fall to Jupiter, the third to Mars, and so on, the twenty-second falling to Saturn again, the twenty-third to Jupiter, and the twenty-fourth to Mars; so that the first hour of the next day (Sunday) will fall to the Sun to preside. By the same reckoning, the first hour of the next day (Monday,) will fall to the Moon, the next to Mars, continued in the same rotation. Hence the days of the week came to be distinguished by the Latin names of *Dies* Saturnii, Solis, Lunæ, Martis, Mercurii, Jovis, and Veneris; and among us by the names of Saturday, Sunday, Monday, &c.

The term of a week or seven days was a period of time used by the Eastern nations generally. The Brahmins employed nearly the same denominations for the days of the week which we now use; so did the Egyptians, Jews, Arabians, and Assyrians, which may be considered as a proof of their common origin.

The Calendar.

NOTE 27, PAGE 113.

THE notion of time was doubtless first impressed upon man by the regular recurrence of light and darkness, accompanied by activity and repose. This gives the idea of that portion of time known as a *day*.

He also observed that comparative heat and cold, upon which depend the various productions of the Earth, recurred after a lapse of a certain number of these intervals of light and darkness, which gave him the notion of a *year*.

In general, nations have marked this portion of time by some word indicating a return of the circle of the seasons. Thus, the Latin *annus* signified a ring; and the Greek ἐνιαυτὸς implies something *returning* into itself. The word *year*, as it exists in the Teutonic languages, of which our word year is an example, is said to have its origin in the word *yra*, which in the Swedish language means a *ring*, and is, perhaps, connected with the Latin *gyrus*, (a circle formed by wheeling round.)

The ancients marked the return of the seasons by the rainy and the dry season, or summer and winter; also by the migration of the different kinds of birds. The rising and setting of certain fixed stars also served to indicate the different portions of the year; thus the rising of the Pleiades in the evening showed the approach of winter, and the heliacal rising of Sirius, which the Egyptians called Sothis, coincided with the rising of the Nile. Hesiod directs the husbandman when to plow and when to reap by the setting of the Pleiades.

By such rude observations it was afterwards determined that the year consisted of at least 365 days. We learn from Herodotus that the Egyptians claimed the honor of discovering this number of days in the year, which they asserted they learned from the stars. The Jews also had a similar reckoning at a very early period.

By this mode of computation the seasons would not return exactly to the same months of the civil year; but instead of being fixed to certain months, after a lapse of time, winter would be found in autumn months and summer in the spring months.

The Roman calendar, a term derived from the Latin *calendæ*, was very rude in its structure until the time of Julius Cæsar. The ancient *Roman year* consisted of 10 months, which, by the reformation of Numa Pompilius, was made to consist of 12. When Cæsar became dictator, by the advice of Sosigenes, an eminent Alexandrian astronomer and mathematician, he adopted the mode of intercalation of one day in four years, which we still retain. This mode of computing time is called *Old Style*, and the calendar containing the account of time according to the Julian method of reckoning is called the *Julian calendar*, which came into use January 1, B. C. 45. The *Julian epoch* is that period included from the time the Julian calendar was first instituted to the time of Christ—viz. forty-six years before Christ.

The day of new moon immediately following the winter solstice in the 707th year of Rome was made the first of January of the first year of Julius Cæsar. The 25th of December of his forty-fifth year is considered as the date of Christ's

nativity; and the forty-sixth year of the Julian calendar is counted the first of the Christian era. The year preceding the birth of our Saviour is called by chronologists the first year before Christ, but by astronomers it is called the year 0.

In order to introduce the new system as established by Julius Cæsar, it was necessary to enact that the previous year—namely, 46 B. C.—should consist of 445 days; for which reason that year was called the "year of confusion," but by Macrobius more appropriately the "*last* year of confusion."

The *Gregorian year* or *calendar* was established by Pope Gregory XIII., in 1582, for the purpose of correcting the errors of the Julian calendar. To this end, Pope Gregory, aided by the most celebrated mathematicians of his time, ordained that a day should be added to the month of February once in every four years; and that on and after the 1600th year of the Christian era, and every fourth century thereafter, should be a bissextile or leap year; thus every year divisible by 4 without a remainder should contain 366 days, and all years divisible by 400 without a remainder should also contain 366 days. By this rule the error amounts to less than a day in 3600 years, which may be avoided by extending the rule; that is, to make all years divisible by 4000 consist of 366 days, which would make an error of only a single day in 100,000 years.

This mode of computation is called the Gregorian, or *New Style*, and is now generally introduced into all the countries of Europe, except Russia.

In order to make any date of the Old Style correspond with the New, we must now add to it twelve days. Thus, General Washington was born February 11, 1731, Old Style, which, happening in the early part of the eighteenth century, eleven days only must be added, which makes his birthday fall on the 22d of February, 1732.* For in England, previous to the year 1732, the year commenced on the 25th of March; therefore the 11th of February would be near the *end* of the year 1731, while according to New Style the year begins the first of January; therefore the date of his birth would be near the beginning of the year 1732.

The *civil year* is that which has been established by government for civil purposes, which consists of an even number of days, the odd hours and minutes not being reckoned. It consists of 365 days, except every fourth year, which contains 366.

Albategnius, an Arabian prince, made observations at Aracte, in Chaldea, towards the beginning of the tenth century; and by comparing his observations with those of former astronomers, he fixed the length of the tropical year to 365*d.* 5*h.* 46*m.* 24*s.* In the year 1252, Alphonsine X., of Castile, obtained the assistance of the best astronomers of his age to arrange a series of astronomical tables, in which we find the length of the year to be 365*d.* 5*h.* 49*m.* 16*s.*, a very near approximation to the truth. These observations were called the Alphonsine Tables.

The period of the duration of the tropical year has been determined by the following observers, namely:

---

* Olmstead's Astronomy, p. 47.

	d.	h.	m.	s.
Nicolas Copernicus, in 1543	365	5	49	6·
Tycho Brahé, in 1602	365	5	48	45·5
Kepler, in the Tabulæ Rudolphinæ, in 1610	365	5	48	57·6
James Cassini, in 1743	365	5	48	52·4
Flamstead, First Astronomer Royal at Greenwich Observatory, 1680	365	5	48	57·5
Halley, in his Astronomical Tables, about 1700	365	5	48	54·8
Lacaille, in his Tables	365	5	48	49·
Bessel, in 1830, for the year 1800	365	5	48	47·8

The *astronomical year* begins on the 31st of December, at noon.

Each year of our calendar, which is almost exclusively in use throughout Christendom, consists of 12 unequal months; but the Turks and Jews make their year to consist of 12 lunar months, or 354 days. A month, according to the English law, is a lunar month, or 28 days, unless otherwise expressed, and a lease for 12 months is only for 48 weeks.* But in some of the United States it has been enacted that whenever the term month has been used, it shall be construed to mean a *calendar*, and not a lunar, month.†

Cycles.

NOTE 28, PAGE 114.

THE cycle of the Sun, or 28 years, multiplied by the cycle of the Moon, or Metonic cycle of 19 years, make 532 years, which is called the *Paschal* cycle, because it serves to ascertain when Easter occurs. This cycle was invented by Victorius of Aquitain, A. D. 463, and was in use until the Roman Empire became extinct.

The ancients ascertained the fact that the new and full moons happen at very nearly the same times of the year after a period of nineteen years. This was marked by the Greeks with letters of *gold.* Hence the number of the year in this cycle is called the *Golden Number.*

The solar and lunar years do not commence together till after nineteen years, during which time the solar years exceed the lunar. The number of days by which the solar year exceeds the lunar is called the *Epact,* which means something *added.*

The *Roman Indiction* was a period of 15 years, appointed by the Emperor Constantine, A. D. 312, for the payment of certain taxes from the subjects of the empire.

At the Council of Nice, A. D. 325, it was decided that Easter-day is the first Sunday *after* the full moon which happens upon or next after the 21st of March. It follows, therefore, that Easter-day cannot take place earlier than the 22d of March, or later than the 25th of April, so that from one date to the other (both inclusive) are thirty-five days. The *Number of Direction* is that day of those thirty-five on which Easter Sunday falls.

The *Julian Period* consists of the cycle of the Sun, or 28 years, multiplied by the lunar cycle, or 19 years, and that product multiplied by the Roman Indiction, or 15 years; which product is 7980 years. Thus $28 \times 19 \times 15 = 7980$. This

---

* 2 Blackstone's Commentaries, 141.

† Bouvier's Law Dictionary, article *Month.*

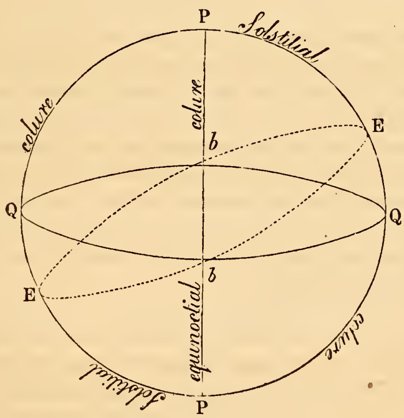
period is reckoned from 4713 years before Christ, when the three cycles are supposed to have commenced together, which circumstance will not occur again until A. D. 3267. In order to find the Julian Period for any given year, add 4713 to the year of Christ. Thus 1860 + 4713 = 6573, the Julian Period for the year 1860.

Ecliptic.

Note 29, Page 115.

To an observer situated on the Sun, the Earth would appear to move in a path among the stars, which we designate by the name of the *ecliptic.* It is the continuation of the plane of the Earth's orbit outwards from the Sun's centre until it reaches the sphere of the fixed stars. If a spectator on the Earth could see the stars in the same direction, but far beyond the Sun, that luminary would appear to be moving through the high constellations of Pisces, Aries, Taurus, Gemini, Cancer, and Leo during the spring and summer; and through the low ones of Virgo, Libra, Scorpio, Sagittarius, Capricornus, and Aquarius in winter. Hence, to us in north latitudes, in summer the Sun seems to rise north of east on the horizon, crossing the meridian at a greater altitude than in winter, and to set north of west, remaining in sight *longer* than 12 hours; while in winter it rises south of east, crosses the meridian farther south than it does in summer, and sets south of west, remaining in sight *less* than 12 hours.

Fig. 214.



Let *fig.* 214 represent the celestial sphere, P P being its poles; then Q Q would be the equinoctial line, being exactly 90° from each pole. E would be the ecliptic, situated 66° 32′ at its nearest approach to either pole, or 23° 28′ at its greatest distance from the equinoctial. P Q E P Q E is a meridian which intersects the ecliptic at its greatest distance north or south of the equator. This meridian is called the *solstitial colure;* and the points where it intersects the ecliptic are called the *solstices,* because when the Sun is vertical at those points he is *stayed* from re-

ceding from the equator. P *b b* P is the *equinoctial colure.* This is a meridian which also passes through the poles, and through those points formed by the intersection of the ecliptic and the equator. These points are called the *equinoxes;* for when the Sun is at those points, the days and nights are equal all over the Earth. Equinoctial is formed of the two Latin words *æquus*, equal, and *nox*, night, signifying equal night.

Cause of the Tides.

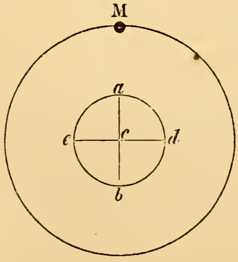
NOTE 30, PAGE 120.

THE alternate rise and fall of the tides twice in a lunar day is immediately owing to the force of gravitation exerted by the Sun and Moon. The action of the Sun and Moon, especially that of the Moon, disturbs the equilibrium of the ocean, the surface of which, were it not for these disturbing forces, would be an ellipsoid, flattened at the poles.

If the Moon were to attract the centre of gravity of the Earth, and all the particles of which it is composed, and also all the waters which cover the Earth, with an equal force, and in the same direction, the oceans would retain their equilibrium, and tides would be unknown. Owing to the Moon's attractive power being inversely as the square of the distance, causing the difference of the intensity and direction of the forces, and consequent disturbance of the equilibrium, the spheroidal form of the water is destroyed.

The particles of water under the Moon are more attracted than the centre of gravity of the Earth; consequently, they have a tendency to leave the surface of the Earth, and are thus heaped up on that side under the Moon, but are retained by their gravitation, which is lessened by the lunar attraction. But the centre of the Earth is more powerfully attracted than the particles of water in the hemisphere opposite to the Moon, so that the Earth has a tendency to leave the waters, but is retained by gravitation, which, however, is diminished by the Moon's attraction. Thus it will be seen why there are two tides at the same time on opposite sides of the Earth; the waters under the Moon are heaped up, forming a tidal wave; and those in the opposite hemisphere are, at the same time, raised above the general surface; for the diminution of the gravitation of the particles in each position is almost the same.

Fig. 215.



Suppose a particle to be at *a*, immediately under the Moon M; it will be as much more attracted than the centre of gravity of the Earth as the square of *c* M (the distance of the Moon from the centre of the Earth) is greater than the square *a* M, the distance of the Moon from the particle at *a*. Hence the particle has a tendency to leave the Earth, but is retained by its gravitation.

In twelve hours the particle *a* is brought to *b* by the rotation of the Earth on its axis, and is then in the opposite hemisphere from the Moon. The Moon attracts it now less powerfully than it attracts the centre of the Earth, in the

ratio of the square of the distance from c M (the distance of the centre of the Earth from the Moon) to the square b M, the distance of the particle b from the Moon. The Earth has now a tendency to leave the particle b, but its gravitation retains it. Thus, when the particle is at a, the Moon draws it from the Earth; and when it is at b, it draws the Earth from the particle; in both instances producing an elevation of the particle above the surface of equilibrium.

The action of the Moon on a particle at d or c, 90° distant from a, may be resolved into two forces—the one in the direction of the radius of the Earth $d\,c$ or $e\,c$, and the other in the direction of a tangent to the surface, which is at right angles to the Earth's radius. The latter force attracts the particle towards the Moon M, and causes it to move along the surface of the Earth towards a, so that there is a depression of the water at d and e at the same time that it is high water at a and b.

Solar and Lunar Tidal Waves.

Note 31, Page 120.

The Sun attracts as powerfully as 354,936 earths would, if they held his place; the Moon attracts but as an 80th part of the Earth; the Sun, however, is 400 times farther from the Earth than he is from the Moon. Now, the amount of the solar and lunar tidal waves is due to the difference with which two opposite sides of the Earth are influenced by solar and lunar attraction; this difference is much less in the case of the large, remote Sun, than in that of the Moon, which is comparatively small and near, because 8000 miles (the Earth's diameter) is a much more trifling quantity, compared with 95,000,000 of miles, than when compared with 240,000 miles. Thus, the great mass of the Sun makes but a small tidal wave, while the small mass of the moon makes a larger one.

The solar tidal wave is so much less than the lunar tidal wave that it is disregarded, excepting as a quantity that sometimes augments and sometimes diminishes the more important lunar rise. If the Earth were at perfect rest, and surrounded everywhere by a thin, even coating of water, the Moon's attraction would so alter the form of the fluid investment, that it would assume the outline of an ellipsoid, 116 inches wider one way than the other. The Sun would, under the same circumstances, make the water find a permanent position of rest in an ellipsoidal outline, 45 inches wider one way than the other. By adding together the *half* of each of these quantities, 81 inches is obtained for the *absolute* height to which the combined influence of the Sun and Moon can raise the surface of the ocean on one side of the Earth.

Spring and Neap Tides.

Note 32, Page 123.

The height of the tides is much increased in syzigies, or at the time of new and full moon; for when the Moon is new, the Sun and Moon are in conjunction, and when she is full, they are in opposition; and therefore are, in both cases, in the same meridian. In each of these positions—that is, new or full moon—the attractions of the Sun and Moon are combined, which produces the highest or spring tides under that meridian, and the lowest in those points 90° distant. The higher

the sea rises in flood tide, the lower it falls in the ebb. The neap tides happen when the Moon is in quadrature, or 90° from the Sun; and as the solar and lunar attraction is not exerted in the same direction, the neap tides do not rise so high nor sink so low as the spring tides.

But the spring tides, which happen when the Moon is in perigee, are considerably higher than those which occur when she is in any other part of her orbit, especially that point most distant from the Earth. As the Moon is once new and once full in every month, there must be two spring tides in every lunation. The greatest tide occurs when a new or full moon happens when the Moon is at the point of her orbit nearest to the Earth, and the Sun vertical at the equator; hence, at the time of the equinoxes, when the Moon is in perigee, the highest tides occur.

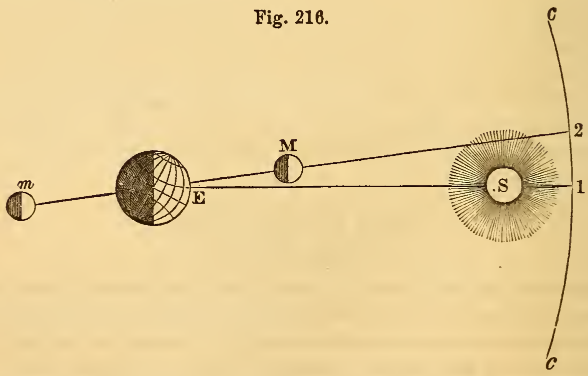
The above description of the phenomena connected with the progress of tidal waves only applies to the open ocean. In narrow channels the progress of the wave is impeded by mechanical obstacles; hence, every particular port in confined seas has its own especial law for the time of high water. The high tide at Brighton, on the coast of England, for instance, occurs half an hour later than it does at Dover; and at Falmouth, six hours later. The wave which enters the English Channel from the German Ocean requires eight hours to travel from Dover to Bristol. The channel of the river Amazon is so long, that there are seven high and seven low tides within its banks at the same time.

Inclination of the Moon's Orbit.

Note 33, Page 126.

Place a plate (which will represent the Moon's orbit) half over the edge of a round table; tilt the plate a little, so that half may be above and half below the top of the table. The surface of the table will represent the Earth's orbit, and the inclination of the plate to the surface of the table will then represent the inclination of the Moon's orbit to the Earth's orbit.

Fig. 216.



In the figure let E 1 represent the plane in which the Earth revolves about the Sun, and *c c* the concave surface of the heavens; M *m* will represent the plane in

which the Moon revolves about the Earth. The line M m is inclined to the line E 1 by the angle M E 1. When the Moon is at M, or that part of its orbit that is nearest to the Sun, an observer on the Earth sees it at 2 in the heavens, along the line E 2; but he sees the Sun at 1 in the heavens, along the line E 1; consequently, when the Moon's orbit is placed as represented in the figure, the Sun cannot disappear behind the Moon.

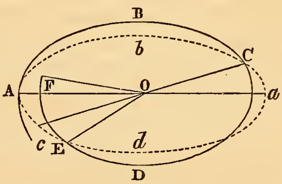
Motion of the Moon's Nodes.

Note 34, Page 127.

Although the Moon's orbit is elliptical, it is not a *perfect ellipse*, its deviation from that figure being observable in every lunation.

When the Moon performs a sidereal revolution, it does not return exactly to the same star again from which it set out; thereby indicating a continual change in the plane of its orbit. The points where the Moon's orbit crosses the ecliptic, called the nodes, are continually changing their places by a constant retrograde motion, which amounts to about 3′ 10″·64 on an average daily. In the period of 18 years and 219 days the nodes perform one complete revolution round the ecliptic, as may be seen by reference to the following figure:

Fig. 217.



Let O represent the position of the Earth, and the dotted line b a d the plane of the ecliptic intersected by the Moon in its revolutions round the Earth. B C D E F represents the Moon's path, which, crossing the Earth's orbit at A, may be called the Moon's ascending node. It will be seen that the Moon's orbit is not in the plane of the Earth's orbit, for the Moon moves along the curve A B, and intersects the Earth's orbit at C instead of a, which would be in the opposite point, or 180° distant from the node A. So that the descending node C is *less* than 180° from the ascending node A. The Moon on leaving C pursues the path C D E F; and instead of intersecting the ecliptic at c, which is 180° from C, it cuts it at E, which is behind the point c in longitude. In this manner the nodes of the Moon's orbit retrograde, until, after the lapse of nearly 19 years, they return to the same place again.

Transits of Mercury.

Note 35, Page 136.

The earliest recorded observations of the planet Mercury date back as far as B. C. 265, on the 19th of the Egyptian month *Thoth.*

The Chinese have recorded observations of this planet as remote as the second century of our era, the accuracy of which have been verified by modern astronomers, among whom is M. Le Verrier.

The first authentic account which we have of the phenomenon of a transit of Mercury was that of November 7, 1631, as computed by Kepler, and observed by Gassendi, at Paris.

In November, 1651, Shakerly, or Schakerlaus, made a voyage to Surat, in the

East Indies, in order to witness a transit of Mercury which would not be visible in England.

Hevelius and Halley also observed transits of Mercury. The latter conceived the idea of finding the Sun's parallax by accurate observations of the ingress and egress of the planet, taken at places widely asunder; but it has been found that the difference of the parallaxes is not sufficiently large to answer the purpose. The transits of Venus are now carefully noted by astronomers for determining the solar parallax, which can be found very accurately by these means.

Lalande, when at the advanced age of 70 years, observed the transit of Mercury which occurred on the 8th of November, 1802. To use his own words—"The passage of Mercury over the Sun's disc was observed this morning for the nineteenth time. The weather was exceedingly favorable, and astronomers enjoyed, in the completest manner, the sight of this curious phenomenon. I was the more anxious to have a view of it, as I shall never see it more."

During the political confusion attending the French Revolution, Lalande busied himself in computing and arranging tables, the correctness of which was proved at the time of this transit. On being congratulated for having escaped the fury of those times, he wittily replied—"I may thank my *stars* for it."

Various phenomena have been recorded by astronomers during their observations of the transits of Mercury. Different observers at the same station have given different results of their observations with several kinds of telescopes. Some have seen the planet "pear-shaped" as it advances on the Sun, just previous to the internal contact. By others a luminous bead of light has been observed on the disc of the planet when projected on the Sun. Luminous rings have also been frequently seen surrounding the planet; at other times, dark or hazy rings have been observed. Many of these appearances are no doubt due to optical illusions.

American Observations of a Transit of Venus.

NOTE 36, PAGE 138.

THE American Philosophical Society of Philadelphia appointed a committee of its members to take observations of the transit of Venus, which was to take place in 1769.

This committee consisted of William Smith, D.D., Provost of the college of Philadelphia; John Lukens, Esq., Surveyor-General of Pennsylvania; David Rittenhouse, A.M., of Norriton, (Norristown;) and John Sellers, Esq., Representative in Assembly for Chester county.

This was one of several committees appointed by that Society for this purpose, all of whom labored under great discouragements for want of proper apparatus, especially good telescopes with micrometers. A part of this discouragement was removed, for the *Provincial Assembly* generously voted the purchase of one of the best reflecting telescopes, with a Dollond's micrometer; and likewise the sum of *one hundred pounds*, for the erection of an observatory and other incidental expenses. These instruments were for the use of the Philadelphia Observatory. But the Norristown Observatory was not yet properly furnished with instruments.

Previous to the appearance of the transit, Thomas Penn, Esq., one of the pro-

prietaries of the province, wrote a letter to the Philosophical Society, at the request of the Rev. Nevil Maskelyne, then Astronomer Royal at the Greenwich Observatory, desiring "that the transit might be accurately observed in Pennsylvania, as the situation was especially favorable." He also sent printed directions for noting the observations.

Incited by this letter of the great English astronomer, they sent over an order for a two and a half feet reflector and a Dollond's micrometer, to be sent from London as promptly as possible. The instruments were immediately forwarded, with a letter from Thomas Penn, which concludes as follows:

"I have sent, by Captain Sparks, a reflecting telescope, with Dollond's micrometer, exact to your request, which I hope will come safe to hand. After making your observation with it, I desire you will present it, in my name, to the college. Messrs. *Mason* and *Dickson* (Dixon) tell me they never used a better than that which I formerly sent to the Library Company of Philadelphia, with which a good observation may be made, though it has no micrometer."

The transit of Venus was also observed by the Rev. Samuel Williams, A.M., at Newbury, (Newburyport,) in Massachusetts.

The following is a portion of a letter received by Thomas Penn, Esq., from the Rev. Nevil Maskelyne, showing the American observations of the transit were highly thought of in Europe:

Greenwich, Aug. 2, 1769.

SIR:—I thank you for the account of the Pennsylvania observations, (of the transit,) which seem *excellent* and *complete*, and do honor to the gentlemen who made them, and those who promoted the undertaking. * * * * * * *

I am, sir, your very humble servant,

NEVIL MASKELYNE.

To the Hon. THOMAS PENN, Esq.

It is said that the care and responsibility which Mr. Rittenhouse experienced in preparing for this transit, and the intense feeling produced on the happy realization of his anticipations, had such an effect upon him that, at the conclusion of his observations, he fainted.

Orbits of Comets.

NOTE 37, PAGE 141.

IN the early ages of the world, comets were regarded as omens of war and pestilence, subject to no laws, but permitted by the Creator to rush wildly through space. By some they were thought to be meteors, which were kindled into a blaze as soon as they came within the atmosphere of the Earth, by which means they were consumed.

They were known to move in elliptical or *long regulated* orbits, even as early as the time of Appolonius Myndius, about B. C. 300. But in their motions they presented strikingly different characteristics from the planets.

Tycho Brahé supposed them to revolve in circular orbits beyond that of the Moon, while Kepler affirmed that they moved in straight lines. Hevelius, towards the middle of the seventeenth century, was the first who remarked that the orbits of comets were curved towards their perihelion, the concave side being turned

towards the Sun. He, as well as Borelli, an Italian astronomer who flourished about the same time, conceived that the orbits of comets might be either parabolic or elliptic. But their orbits were unknown until Dörfel, a Saxon astronomer, in 1681, proved that the orbits of many comets are parabolas, with the Sun in the focus. Newton was led, by his discovery of gravitation, to conclude that comets move in conic sections; and that, on account of their great eccentricity, they might be assumed to be parabolas near the perihelia.

Since the discovery of the law of gravitation, it has been determined that any body revolving round the Sun must move in one of those curves called the *conic sections*—namely, the circle, the ellipse, the parabola, or the hyperbola—and that the Sun must be situated in one of the foci of the curve. The orbit may vary in magnitude, position, or direction, but it must be one of the above-mentioned curves.

The orbits of the comets do not coincide with the plane of the ecliptic, but may be found at every possible angle with it. Unlike the planets, the comets do not move in the same *direction* round the Sun—that is, from west to east—but revolve in all directions and with all possible inclinations.

Thus it may be seen that the orbits of the comets, although subject to the law of gravitation, are nevertheless very different from those of the planetary bodies of our system.

Comets which visit the Sun but once, and then sweep off into space, (perhaps to visit other systems,) have *hyperbolic* orbits; for the extremities of hyberbolas run off from each other forever. Hyperbolically-moving comets must be looked upon as strangers to our Sun's system; for possibly all comets may be wanderers, passing from sun to sun, and only sojourning near to one system for a time, when caught by the influence of its attraction. A comet moving in a hyperbolic path may approach so near to some planetary body as to have its velocity of motion retarded, and its hyperbolic path converted into an elliptical one. If the velocity of a body moving in a hyperbola be diminished, the motion at once becomes elliptical; and if, on the other hand, the velocity of a body moving in an ellipse be increased, the motion becomes hyperbolic. It is known that the comet of 1770, commonly called Lexell's comet, has been drawn into a new path in consequence of having passed very near to the planet Jupiter.

Discovery of Telescopic Comets.

NOTE 38, PAGE 143.

NEARLY every year furnishes us with the discovery of one or more new comets. Astronomers are now on the alert to detect these numerous wanderers as soon as they appear within the limits of telescopic vision.

In 1840, the late king of Denmark offered a prize gold medal to the discoverer of every new comet. On the first of October, 1847, Miss Maria Mitchell, of Nantucket, perceived a nebulous body a few degrees from the North Pole, which, on the following evening, had so much changed its place as to confirm the suspicion of its being a comet. This discovery having been made known to the king of Denmark, the gold medal was awarded to Miss Mitchell, who was the first American, and the only *lady*, who has ever received it. This comet was also seen on

the 3d of October, by De Vico, at Rome; on the 7th, by the Rev. W. R. Dawes; and on the 11th, by Madame Rümker, at Hamburg.

Every comet is carefully noted as soon as observed, and its elements recorded; so that in future time these observations may lead to important discoveries in cometary astronomy.

Tails of Comets.

Note 39, Page 147.

The comet's tail cannot be an emanation *drawn out* by the Sun's attractive influence, for it is always turned *away from* the Sun. Neither can it be matter *left behind* during the comet's rapid motion, for after the perihelion passage it goes *before* the nucleus instead of following it. It seems rather to be some mysterious exhalation, raised by the power of the Sun's influence, and then subjected to the rule of some strange and yet unknown agency, which must, however, be of a different nature from gravitation. The tail of the comet of 1680 shot out through its hundred millions of miles in length in *two days*. The tail of the comet of 1843 could not have had inferior dimensions, and yet this wonderful appendage was brandished round through half a circle while the comet passed through its perihelion curve, the end of the tail sweeping through a bending line some 300,000,000 of miles long in *two hours* of time. Herschel beautifully likens this comet's tail to a negative shadow, as it moved through its perihelion passage.

Halley's Comet.

Note 40, Page 152.

On the appearance of Halley's comet, in 1835, it seemed to be a spherical mass of vapor without a tail; but as it approached its perihelion, its tail increased to thirty or forty degrees in length.

Soon after its appearance in that year, it was observed by M. Struve, at Dorpat; the nucleus resembled a fan-shaped flame, emanating from a bright centre, after which it assumed the appearance of a red-hot coal of an oblong form. In a few days its appearance is described as resembling the stream of fire which issues from the cannon's mouth after a discharge, when the sparks are driven backward by a violent wind.*

M. Struve saw distinctly a central transit of a star of the ninth magnitude through the nucleus of the comet. The star remained constantly visible, without any considerable diminution of light; and instead of being eclipsed, the nucleus of the comet became invisible, owing to the superior brightness of the star.

But great and sudden changes have been observed in this comet, sometimes in very short intervals of time. On one occasion, the nucleus appeared clear and well defined; and in the space of a few hours it became obscure and much enlarged. On another occasion, luminous brushes or sectors appeared, diverging from its centre through the nebulosity. M. Struve describes the nucleus of the

---

* For further information on this subject, see a Treatise on Comets, by J. Russell Hind, and Herschel's Observations at the Cape of Good Hope.

comet, as observed by him on one occasion, as elliptical, and like a burning coal, out of which there issued, in a direction nearly opposite to the tail, a divergent flame, varying in intensity, form, and direction, and sometimes appearing double, and resembling a luminous gas issuing from the nucleus. M. Arago saw three divergent flames opposite to the tail. Sir John Herschel, at the Cape of Good Hope, saw these luminous fans. When it appeared in the year 1682, brilliant flames similar to those above described, were observed by Hevelius.

On the appearance of this comet in 1682, Halley, at the suggestion of Newton, searched all ancient and modern records in order to discover any similarity between the elements of former comets and the one then visible; and from an examination of all the facts, he ventured to predict its reappearance about the year 1758 or 1759.

As the time drew near for the verification of this great prediction, astronomers were all anxiety, for that great philosopher (Halley) did not live to see the fulfilment of his prophecy. In order to compute the disturbing effects of the primary planets upon this comet, it was necessary to calculate them for a period of 150 years, which is equal to two revolutions of the comet. This task was accomplished by Clairault and Lalande. The latter undertook the arithmetical calculations, assisted by Madame Lepaute, the wife of a Parisian watchmaker. "During six months," says Lalande, "we calculated from morning to night, sometimes even at meals; the consequence of which was, that I contracted an illness which has changed my constitution for the remainder of my life. The assistance rendered by Madame Lepaute was such that without her we never should have dared to undertake this enormous labor, in which it was necessary to calculate the distance of each of the two planets, Jupiter and Saturn, from the comet, separately for every successive degree, for 150 years."

The name of Madame Lepaute is not mentioned by Clairault in his memoir announcing the completion of their labors, which Lalande said was owing to his fear of arousing the jealousy of another lady to whom he was attached.

Madame Lepaute assisted Lalande in many other calculations, and by this means so weakened her sight, that finally she was forced to relinquish all arithmetical labors.

These stupendous calculations being finished, Clairault announced the result of their joint labors in a communication to the Academy of Sciences of Paris, in which he predicted the next perihelion passage of the comet on the 18th of April, 1759, but which he afterwards changed to the 11th of that month. It actually passed its perihelion on the 13th of March, within 22 days of the time assigned by Clairault.

Its next appearance, in 1835, happened within a few days of the predicted time.

Lexell's Comet.

NOTE 41, PAGE 154.

LEXELL'S comet of 1770 passed within six times the Moon's distance from the Earth, and was considerably retarded in its motion in consequence of the terrestrial attraction for its mass. But it did not in return produce the slightest effect,

even in the tidal rise of our ocean. Had the comet's mass been equal to that of the Earth, the length of the year would have been increased three hours by its retarding power over the Earth's motion. The length of the year was not, however, increased so much as the smallest fraction of a second; and hence it can be shown that the comet's mass could not be so great as a five-thousandth part of the Earth's mass. The extreme thinness of the comet's substance seems to be due to the absence of any central dense matter capable of controlling the elasticity of the cometic material. If the Earth were to retain its present size, and yet be reduced to the one-thousandth part of its actual mass, the atmosphere would leap out to considerably more than one thousand times its present dimensions. Newton has shown that a globe of air of an inch diameter, if reduced to the density it would have when removed four thousand miles from the Earth's surface, would be sufficient to fill a sphere exceeding in its circumference the orbit in which Saturn moves; and of some such material as this the cometic vapor must be composed.

Precession of the Equinoxes.

Note 42, Page 165.

The protuberant matter of the Earth's equator exercises a disturbing influence over the Moon's motions; and the Moon in return attracts it, and deranges the Earth's rotation, to a certain extent, in consequence. It is the Moon's attracting the protuberant zone of the Earth's equator, sometimes one way and sometimes another, that gives the vacillation to the Earth's rotation, causing the *precession of the equinoxes*. The Sun also exercises a disturbing influence over the protuberant mass of the terrestrial equator.

This vacillation, or conical sweep of the Earth's axis, is caused by the masses of the Sun and Moon attracting the protuberant matter at the equator of the Earth, sometimes one way and sometimes the other way, accordingly as they are placed with regard to it. The immediate consequence of this conical sweep of the Earth's axis is to cause the equator to intersect the ecliptic in some new point at each revolution. The points of intersection travel backwards upon the ecliptic, or from east to west, fifty seconds and a tenth every year. After 25,868 years, these points of intersection will have gone completely round the circle of the ecliptic. As the two points where the plane of the equator intersects the plane of the Earth's orbit (*i. e.* the ecliptic) are called the equinoctial points, this travelling back of the points of intersection is called the "*precession of the equinoxes.*"

The precession of the equinoxes was discovered by Hipparchus, the most celebrated astronomer of antiquity. On comparing his observations of the longitudes of several stars which were made about 128 years before Christ, with those made by Timocharis and Aristillus 155 years earlier, he found that in that interval the longitudes of the stars had increased more than could be accounted for by any errors of those astronomers.

By comparing the eclipses of the Moon of his own time with those observed by Timocharis, he found that the longitudes of all the stars increase perpetually; which is owing to the precession of the equinoxes. This motion has carried the

stars through one sign of the zodiac from his time to ours; and, in order to complete one revolution, would require no less than 25,868 years.

As the equinoxes have retrograded about 30°, or one sign, since the time of Hipparchus, it follows that the stars which were then in Aries are now in Taurus, and those which were in Taurus have receded into Gemini, and so on. Or, more properly, the sign Aries is now in the constellation Pisces, and the sign Taurus in the constellation Aries, &c.

It should be distinctly understood that the attributed changes in the positions of the heavenly bodies, owing to the retrogradation of the equinoctial points, are entirely arbitrary; for if a fixed star had been adopted as the point from whence to reckon longitudes and right ascensions, there would have been no such thing as precession; all the longitudes and right ascensions would have remained constant, or nearly so, for ages.

Nutation.

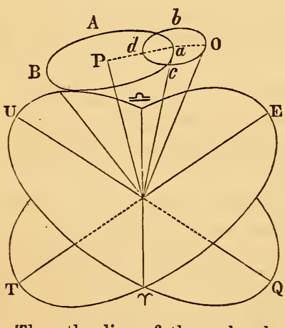
Note 43, Page 166.

All the heavenly bodies, whether fixed or in motion, are affected to a certain extent by the nutation of the Earth's axis; but the amount of variation can be easily calculated for any required time.

Science is indebted to Dr. Bradley, formerly Astronomer Royal at Greenwich, for his discovery and explantion of this apparent displacement in the situations of the celestial bodies.

The Moon being so near the Earth occasions disturbances in the motions of both bodies. Thus, the action of the Moon on the matter of the Earth's equator produces a nutation in the axis of rotation; and the reaction of that matter on the Moon is the cause of corresponding nutation in the lunar orbit.

Fig. 218.



In *fig.* 218, let U ♈ Q and T ♈ E be the planes of the equinoctial and ecliptic, and O P their poles. Then suppose O, the pole of the equator, to revolve with a tremulous or wavy motion in the little ellipse O *c d b* in about 19 years, both motions being very small, while the point *a* is carried round in the circle A *a* B in 25,868 years. The tremulous motion may represent the half-yearly variation, the motion in the small ellipse gives an idea of the nutation, and the motion in the circle *a* A B arises from the precession of the equinoxes. The greater axis O *d* of the small ellipse is 18″·5, its minor axis *b c* is 13″·74.

Thus the line of the poles describes an acute conical surface once in every 19 years, of which the vertex is at the centre of the Earth; and the intersections with the celestial sphere are two equal ellipses, whose transverse and conjugate axes are respectively 18″·5 and 13″·74: the former being always directed towards the poles of the ecliptic.

Refraction.

Note 44, Page 168.

The laws of refraction, although imperfectly understood until the time of Descartes, in the first half of the seventeenth century, were the object of inquiry among the ancients. Archimedes, who lived 291 B. C., is said to have written a treatise, entitled "On a Ring seen under Water," in which he treats of some of the phenomena attendant on refraction. Seneca remarks that an oar in clear water appears broken; but not being able to give a sound philosophical solution to the problem, wisely concludes that "nothing is so fallacious as our sight."

Ptolemy, who lived in the second century, as well as many other ancient observers, remarked the effect of refraction on the rising and setting of the heavenly bodies. As he was one of the most distinguished scientific men among the ancients, the discovery of refraction was by some imputed to him. He certainly made some valuable observations in order to determine its law. Many of the instruments which he used were of his own invention. He composed the Συνταξις μεγαλη, *Syntaxis Megale*, the "Great Composition," which is the only complete systematic work on astronomy ever produced by the ancients. To the word *Megale* the Arabians added the particle "Al," and called it "*Almaghesti*," which we have corrupted to Almagest. This work was a collection of a great number of the observations made by Hipparchus, as well as other ancient astronomers; and also contains problems relating to astronomy and geometry. It contains a catalogue of the fixed stars then known, with their places, as well as numerous records and observations of eclipses, the motions of the planets, &c., all of which are very valuable to the astronomer. A very excellent edition of this work has recently appeared in Germany.

The first sound views upon the subject of refraction occur in the works of Alhazen, an Arabian mathematician, who flourished about A. D. 1000. In lib. vii. he asserts that "*refraction takes place towards the perpendicular*," which he proves by experiments, and which is certainly one step towards the discovery of the laws which govern it.

Roger Bacon, a Franciscan monk, gives a tolerably correct explanation of the effect of a convex glass; and Vitellio, a Pole, who lived in the thirteenth century, wrote an excellent treatise on optics, and explained many of the phenomena produced by refraction.

Tycho Brahé made some corrections for atmospherical refraction; but from all the facts which had yet been collected no exact laws had been traced. In 1604, Kepler published a "Supplement to Vitellio," in which he nearly stumbled on the law of refraction; but after devising an almost endless variety of formulæ, (as was his custom,) he failed to discover it. He tried numerous constructions by triangles, conic sections, &c. without success, and at last was obliged to content himself with an approximate rule.

The law of sines was discovered by Willebrord Snell, a Dutch mathematician, about 1621, and was afterwards published by Descartes as his own. This last-named philosopher, however, gave the first correct explanation of the rainbow. At length, in 1672, the immortal Newton perfected the theories of his prede-

cessors, and gave the true law of refraction, which is, that in the *same medium* "*the ratio of the sines of the angles of incidence and refraction is constant;*" but this ratio varies with the refracting medium.

Many curious and interesting phenomena are produced by the refraction of light. An instance is related by William Latham, Esq.,* in which he saw the French coast from the town of Hastings, which is situated on the southern coast of England. The French coast is more than 50 miles from Hastings, yet the different towns on the opposite shore were distinctly visible; and by the aid of a spy-glass, the French fishing-boats were plainly distinguished. This curious phenomenon continued for more than three hours. As the convexity of the Earth would conceal the French coast, it proves that the peculiar refractive power of the atmosphere on that occasion brought it into view by bending the rays of light, and thereby raising it above the horizon to the observer on the English coast. Dr. Wollaston proved such phenomena to be owing to the refraction of the rays of light through the media of different densities. One of his experiments is that of heating a poker red hot and observing any object in a line with it; two images are seen—the one direct, the other inverted.

He produced the same effect by a saline or saccharine solution with water, and spirit of wine floating upon it. In 1818, Captain Scoresby, while in the Polar seas, saw the inverted image of his father's ship, although it was then really below the horizon, and thirty miles distant. This phenomenon, like the former, may be explained by the refraction of the rays of light through atmospheric strata of very different densities.

Aberration.

Note 45, Page 172.

Although the discovery of aberration might have been made without observation, yet the fact was found out before it was seen, as a consequence of reasoning. It seems clear, that since light and the spectator on the Earth are both in motion, the apparent direction of an object will be determined by a composition of these motions. The aberration of light, the greatest astronomical discovery of the eighteenth century, belongs to Bradley, then Professor of Astronomy at Oxford, and afterwards Astronomer Royal at Greenwich. Bradley and Molyneux, in 1725, were making observations in order to discover the existence of the annual parallax of the fixed stars; but Bradley found a minute apparent motion which the annual parallax could not produce. In 1727, he resumed his observations with a new instrument, but again without success; for he was still at a loss to account for this apparent motion. At last accident favored him, by turning his inquiries into the right channel. Being one day in a boat on the Thames, he observed that the vane on the top of the mast indicated a different direction for the wind as the boat changed her course. Here he found a solution of his problem. The boat represented the Earth moving in different directions in different seasons; the wind was the light of a star. Thus the phenomenon was found to be an optical illusion, occasioned by a combination of the motion of light with the

* Phil. Trans. 1798, vol. lxxxviii.

motion of his telescope. He now traced the consequences of this idea, and found the answer to his inquiries. In 1729 he communicated his discovery to the Royal Society. His paper is a very happy narrative of his labors. His theory was so sound that it has never been contested, and his observations so accurate that the quantity which he assigned as the maximum of change, amounting to one-ninetieth of a degree in declination, has scarcely been altered by more recent astronomers. The aberration of light also affords a direct proof of the motion of the Earth in its orbit.

Proper Motion.

Note 46, Page 172.

The idea of a proper motion of the stars was vaguely expressed by Lucretius; and it was thought that but for such a motion all the bodies belonging to our system would fall together, and form one chaotic mass.

Halley conceived the whole solar system, with the stars, to be in motion round some unknown body, the centre of gravity of the grand whole. But what that great centre is, or where it is situated, is yet a mystery.

> "As God in heaven
> Is centre, yet extends to all."—Milton.

Halley's theory as to the proper motion of the stars has never fallen to the ground, but has been maintained by Le Monnier, Cassini, and others. Tobias Mayer, a German astronomer, who lived about the middle of the eighteenth century, made numerous observations, all tending to confirm the fact. He thought that the changes observed might be accounted for by a progressive motion towards a certain quarter of the heavens. John Henry Lambert, one of the ablest geometricians of the eighteenth century, in his *Cosmologische Briefe*, (1761,) suggested that the stars in the universe are collected into systems, that all these systems are in motion, and that the individual stars of each system move round a common centre of gravity; that all the systems of the universe, as a whole, revolve about some grand centre as a grand whole, which alone of all the creation can be in a state of absolute rest.

The possibility of the motion of our Sun in space was treated on theoretical principles by Dr. Wilson, of Glasgow. M. de Lalande deduced the same opinion from the rotary motion of the Sun, supposing that the same force which causes it to revolve on its axis would also give it a motion of translation in space.

Sir William Herschel, after a variety of observations and calculations, which he transmitted to the Royal Society, remarks, that from the time the proper motion of the stars was first suspected by Halley, we have had continued observations to show that Arcturus, Sirius, Aldebaran, Procyon, Castor, Rigel, Altair, and many more, are actually in motion; and considering the short time during which we have had observations accurate enough for the purpose, it may rather be wondered at that we have already been able to find the motions of so many, than that we have not succeeded in discovering the like alterations in more. Besides, we are well prepared to find numbers of them apparently at rest, as, on account of their immense distance, a change of place cannot be expected to become visible

to us till after thousands of years of careful attention and close observation, admitting every one of them to have a progressive motion. This consideration alone would lead us strongly to suspect that there is not, strictly speaking, one *fixed* star in the heavens; but many other facts will render this so obvious, that there can hardly remain a doubt of the general motion of all the starry systems, and consequently of the solar one among the rest. See *Phil. Trans.* 1783, vol. lxxiii.

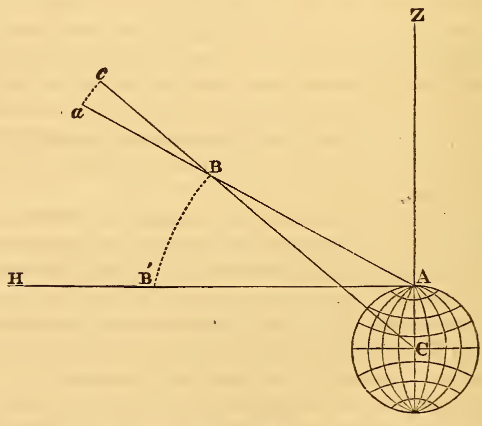
Parallax.

Note 47, Page 175.

The most casual observer will see that the Sun, the Moon, and those celestial bodies which we call planets, have each a particular path, which does not occupy the same point in the heavens for any two consecutive days. If the Moon should be near a bright star this evening, to-morrow its relative situation will be changed; it will have moved, and the star will have retained its position with respect to the other bright stars near it, proving conclusively that the Moon is constantly changing its position in the space which separates it from the stars. The same observations will hold good with the Sun and the planets. It is known that the volume of the Sun is nearly 1,400,000 times that of the Earth, that Jupiter is nearly 500,000,000 of miles from the Sun, &c. These assertions are astounding to those not conversant with the powers of the geometrician to measure inaccessible distances; but that subject may be elucidated by a figure.

It is well known that *the sum of the three angles of any triangle are equal to two right angles*, or 180°.

Fig. 219.



Let us imagine an astronomer situated at A on the Earth. A C (*fig.* 219) should measure the angle B A Z, or the distance of the celestial body situated at B from the zenith Z, which is the complement of the angle B A H, (the height of B from the horizon at A,) or, what is the same thing, the difference between B A H and 90°. He will find that the angle B A C is a supplement to the angle B A Z, or that the angle B A C is 180°, *minus* the angle B A Z.

If, at the same time, a second observer, situated at C, the centre of the Earth, measure the angle B C Z, the distance of B from the zenith Z, then in the triangle A B C will be found the three elements necessary to find the distance B C of the body B from the centre C of the Earth.

Thus the distance of B from C may be found by a simple trigonometrical process, although the point B be inaccessible; for, by observing B from the two extremities of the line A C, the length of which is known, and noting the angle it makes with each end of this line, its distance may be ascertained.

From the points A and C the star B is referred to *a* and *c* among the stars, and this celestial arc *a c* measures the angle B, which is called the *parallax* of the body B: thus, the parallax of the Sun or a planet is the angle, under which a spectator situated on that body would see the radius A C of the Earth; it is also the arc *a c* of the apparent displacement of the body as seen from the point A and the centre C of the Earth.

When the body is situated at B′ on the horizon of the spectator at A, the parallax A B′ C is said to be *horizontal*, which is the greatest parallax a star can have, situated at the distance B C or B′ C when seen in the horizon; for it may easily be seen that as the body rises towards the zenith, the lines A B and C B coincide more and more nearly with C Z, until finally they are united. Thus, the parallax of a body *decreases* as it approaches the zenith, at which point it vanishes altogether.

When the Moon is in the horizon at the moment of rising or setting, an imaginary line drawn from her centre to the eye of the spectator, and another drawn to the centre of the Earth, would form a right-angled triangle with the Earth's radius. Now, the radius of the Earth is known to be 3958 miles; and as the angle at the Moon can be measured, all the angles and one side of the triangle being given, the Moon's distance from the Earth's centre may be found by the rules of trigonometry. Simultaneous observations were made at Berlin and the Cape of Good Hope on the zenith distance of the Moon at the time of her passage of the meridian on a certain day, from whence her mean horizontal parallax was found to be 3454″·2, which gives the mean distance of the Moon from us equal to sixty semi-diameters of the Earth, or 240,000 miles, nearly.

This method, however, is not sufficiently accurate for finding the distance of a body so remote as the Sun. In order to discover the distance of our central luminary, observations of the transits of Venus have been accurately taken. When that planet is in, or within 1¼° of, her nodes, she is sometimes seen to pass over the Sun's disc like a black spot. If the semi-diameter of the Earth had no sensible magnitude at the Sun or Venus, the line described by the planet on the Sun's disc and the duration of the transit would be the same wherever it would be seen from the Earth; but as the Earth's radius has a sensible magnitude as seen from the Sun, the line described by Venus in her passage over the Sun's disc varies in position according to the station of the observer. As the line described by the planet varies according to the position of the observer, so does the duration of the transit. These differences of time are entirely owing to parallax. The transit of 1769 was observed in different parts of the Earth; that at Otaheite was the object of Captain Cook's first voyage. From the observations made at that time,

the Sun's parallax was found to be about 8″·6, which gives nearly 96,000,000 of miles as the mean distance of the Earth from the Sun.

The parallax of the fixed stars is found by assuming the diameter of the Earth's orbit as a base line, and even this enormous extent is too minute to subtend any angle at the distance of most of the fixed stars, comparatively few having been found to have any sensible parallax. As far as our observations have extended, the star α Centauri has a greater parallax than any other; yet its distance is such that the orbit of the Earth, when seen from it, appears like a mere point. Thus, at the nearest fixed star, our whole system of Sun and planets, if viewed through a good telescope, would appear so small that it might be covered by a spider's thread.

Distances of the Stars.

Note 48, Page 177.

The distances of the fixed stars have hitherto been considered too immense for the astronomer ever to hope of measuring or calculating with even an approximation to the truth. The diameter of the Earth was found to be too minute a base for such immense triangles as those required to measure the bounds of our solar system; therefore all hope of estimating the distances of the stars was for a time extinct. But by enlarging the base, by substituting the vast diameter of the Earth's orbit, it was thought the problem might easily be solved. Even this distance of 190,000,000 of miles was found an insufficient base, and, until very recently, defied every refinement of modern observation.

Piazzi, a celebrated Italian astronomer, and, after him, Professor Bessel, a Prussian astronomer, discovered an unusually great proper motion in the star marked No. 61, in the constellation Cygnus, according to Flamstead's catalogue of stars. This star is double when viewed through a good telescope, and observation has assigned a period of about five centuries for the one star to revolve round the other. Besides this, they are travelling together through space at the incredible velocity of six thousand millions of miles in an hour. Yet, at the immense distance which it is situated from us, the path which that star pursues appears to be a *straight line.*

The observations on 61 Cygni were continued diligently for three or four years, and the reward of those labors was, the discovery of a parallax of a little less than one-third of a second. An arc of one-third of a second is equal to the 657,700th part of the radius. Thus, if the distance of a star be the radius of a circle of which the distance of the Sun from the Earth, or 95,000,000 of miles, is an arc measuring only one-third of a second,—which, as before stated, is equal to the 657,700th part of that radius,—it follows, that the distance from the Sun to the star must be 657,700 times the distance of the Sun from the Earth; which would equal 58,880,525,000,000 of miles, an expanse far beyond the powers of human conception. Light, which travels at the rate of nearly 200,000 miles in a second of time, would require more than nine years to accomplish the journey.

The electric fluid travels at the mean rate of 20,000 miles in a second under ordinary circumstances; therefore, if it were possible to establish a telegraphic communication with the star 61 Cygni, it would require ninety years to send a message there.

For the very nice and accurate researches of Professor Bessel, the Royal Astronomical Society of London awarded him a gold medal—"Researches," says Sir John Herschel, "which have gone far to establish the existence, and to measure the quantity, of a periodical fluctuation, annual in its period and identical in its law with parallax.

The parallax of α Centauri, one of the brightest stars in the southern hemisphere, amounts to a second of space; consequently it is nearer to the Earth than any star that is known. Professor Henderson and Mr. Maclear have fully confirmed the annual parallax of this star to amount to a second of arc, consequently it is not so distant as 61 Cygni; for a parallax of one second gives about twenty billions of miles as its distance from our system; a ray of light would arrive from α Centauri to us in a little more than three years, and a telegraphic despatch would arrive there in thirty years.

The Milky Way.

NOTE 49, PAGE 181.

It has been found that by increasing the power of our telescopes, more and more stars are brought into view, verifying Halley's supposition that the number of the stars is so great, that if we cannot call it infinite, it is too vast for a finite number to represent. Their distances, too, from each other, are only to be expressed by infinite numbers. These nocturnal suns are beyond expression innumerable, and the most ardent imagination fails to set any bounds to the extent of the universe.

Our Sun is supposed to be one individual star, forming only a unit in a cluster of many millions, and occupying a place among those minute bodies whose combined light forms the Milky Way, which is itself a ring, of which there are thousands to be seen in the realms of space by the aid of telescopes. These rings or clusters are composed of suns like ours, each one of which, doubtless, forms the centre of a planetary system. And if our Milky Way or cluster of stars be viewed from some of these other milky ways or distant clusters, it would no doubt appear like a small collection of whitish, cloudy light, being too distant to be resolved into stars. Such is the immensity of the creation, of which, perhaps, we see but a minute part of the grand whole!

Sir William Herschel supposes the stars to be scattered over an indefinite portion of space in such a manner as to be almost equally distributed. Those stars of the first magnitude he assumes to be the nearest to our system; those of the second magnitude, at double the distance from us; those of the third magnitude, at three times the distance, and so on. Then supposing a star of the seventh magnitude to be seven times as distant as a star of the first magnitude, it follows that an observer enclosed in a globular cluster of stars, and not far from its centre, could not be able to see the boundary of the cluster by the naked eye. If he should be enclosed in a ring or annulus, he might, through the opening of the ring, see neighboring clusters, which, to him, would seem like patches of faint, whitish cloud. His own zone or milky way would appear to surround the heavens, which would be studded with stars of all degrees of brilliancy. In such a situa-

tion he would naturally conclude that these stars, of which he cannot see the ten-thousandth part, must comprise the whole extent of the universe. Now, give him the telescope, and soon he begins to suspect that the milky zone is composed of stars whose individual lustre could not be appreciated by the naked eye. He now discovers numberless nebulous patches, apparently components of his own system, which to him comprehends every celestial object. By increasing his telescopic power, he finds these nebulous patches to consist of innumerable stars, while other nebulous patches of milky light are revealed. These in their turn are resolved into stars by the use of higher telescopic power; and the astonished observer finds that he has only just set out on his voyage of discovery; that in distant regions there are thousands of milky ways of even more stupendous extent than his own, although *that* may boast of having a diameter of *hundreds of billions of miles.* Should he now be armed with a giant telescope, like that of Lord Rosse, and in the profundity of space find a cluster of thousands of stars whose distance is barely within the penetrating power of his instrument, he would have a range of vision of no less than 11,765,475,948,678,678,679, or eleven trillions, seven hundred and sixty-five thousand four hundred and seventy-five billions, nine hundred and forty-eight thousand six hundred and seventy-eight millions, six hundred and seventy-eight thousand, six hundred and seventy-nine miles!!!

New Star in Cassiopeia.

Note 50, Page 186.

The new star in Cassiopeia, which appeared in 1572, and by some called Tycho Brahé's star, was first seen at Wittemburg, by Schuler, in August of that year; by Hainzel, at Augsburg, on the 7th, and by Cornelius Gemma on the 9th, of November. But as there is no reason to suppose there was in those days any communication between the observers, the discovery of each may be considered as independent of the other. It was seen by Tycho Brahé on the 11th of November, and attracted a great deal of attention among the learned as well as the illiterate.

It increased in brilliancy rapidly, until it surpassed Sirius in splendor, and became visible in the daytime: thus it was watched continually. It did not retain this great splendor for a long time, but gradually decreased in brilliancy till March, 1574, when it disappeared.

Tycho Brahé had studied chemistry and astronomy in Copenhagen and Leipsic, and on his return to Denmark, in 1571, on account of his superior attainments, was invited by the king to his court. Tycho had just fitted out apartments for an observatory and laboratory, in which he spent much of his time. His observatory was furnished with the best instruments of the times, and was the object of much curiosity. It was the following year, 1572, after Tycho's instruments were adjusted, that this brilliant star appeared. A writer of the time says: "By a strange instinct of Providence, were those admirable instruments made and erected by Tycho a little before the appearing of this starre, as if either the starre had stayed for his tooles, or he had foreseen the birth of that starre." Tycho's attention had been turned to alchymy, by which he expected to turn the baser metals into gold; but the sudden appearance of the brilliant star

dissipated all those visions, and roused him to active exertions in his observatory. He made tolerably correct observations of the place and magnitude of the new star, but at first refused to publish them, saying that he considered it "a disgrace for a nobleman either to study such subjects or communicate them to the public."

Tycho conjectured that this new star might have been formed by a sudden condensation of nebulous matter; and since then M. Arago has advocated the same opinion.* Professor Stephen Alexander, of Princeton, New Jersey, considers the facts as consistent with supposed changes of density of the mass, and that the material which had been rapidly condensed would, by increased rapidity of rotation, be soon dispersed in all directions round the centre. It is not a little curious, moreover, that the changes in color which were observed are not, upon the whole, inconsistent with the supposed changes of density and distribution of material.†

If, however, this star should be identical with those which appeared in 945 and 1264, it must be periodical or variable. Sir John Herschel thinks it possible it may appear again about the year 1872. Dr. Dee, an English divine of great learning, and an astrologer, suggested the idea that the new star might move in a direct line to and from the Earth, which he thought might account for its sudden appearance and disappearance.

By the astrologers of the time the appearance of the new star was considered as portending some great event. This star was first white, then yellow, afterwards red, and finally bluish or grayish, which induced La Place to suppose that its changes were owing to the action of fire. Mrs. Somerville says that "it is impossible to imagine any thing more tremendous than a conflagration that could be visible at such a distance." But Captain Smyth, in a conversation with this learned lady, says that she was not at all inclined to grant that so vast a conflagration was within the limits of probability.

Meteorites and Aerolites.

Note 51, Page 197.

All unusual appearances in the heavens, such as comets, auroras, &c., were by the ancients classed together as meteors. But meteors appear in the clear sky, dart along through the heavens, and generally disappear without noise, and without the fall of any residuum or of any tangible substance whatever; whereas meteorites usually explode with a loud noise, which is often attended by the fall of stones greatly heated, and incrusted by a shining, black substance.

Great falls of meteoric stones are recorded in the Chinese annals as early as B. C. 700; and Aristotle, who lived 300 years before our era, supposed the same phenomenon to be caused by fragments of rocks having been raised by whirlwinds, and after remaining for a time in the regions of space, have again found their way to our Earth. Showers of stones are mentioned by both Pliny and Livy. Some of the Greek philosophers attributed to them a solar origin. Pliny says that Anaxagoras, an Ionian philosopher, who lived in the fifth century before Christ,

---

* See *Annuaire, pour* 1842, pp. 432, 433. *Delambre, Histoire de l'Astronomie Moderne.*
† American Astronomical Journal, vol. ii. p. 149.

even predicted a fall of aerolites from the Sun. Diogenes Laertius entertained the opinion that the enormous meteorite which fell at Ægos Potamos, B. C. 465, had been projected from the Sun.

As meteorites appear to have a common origin, many philosophers have supposed them to be fragments of the rocks of the Moon ejected by lunar volcanoes; those luminous spots on the unilluminated part of the Moon's disc having been ascribed to light emitted by burning mountains. The opinion that meteorites are fragments thrown from lunar craters was first entertained by Terzago, an Italian philosopher, in the year 1660, on the occasion of the fall of a meteorite at Milan, which killed a Franciscan monk. But the velocity of projection must be equal to more than 20 miles in a second in order to throw these masses of stone beyond the influence of the Moon's attraction, whereas the projectile force of any terrestrial volcano is not equal to one mile in a second; therefore it seems highly improbable that meteorites can be of lunar origin.

Some remarkable obscurations of the Sun are said to have happened, which, if true, the causes would be difficult to explain. For instance, in the year 1090, the Sun was obscured for three hours, and in 1203 during six hours, although the sky was cloudless. In 1547, an obscuration of the Sun occurred at midday, with a clear sky, and continued for three days, during which time the stars were always visible. Kepler attributed this phenomenon to a *materia cometica*, or to a black cloud formed by certain material exhalations from the Sun itself.* The obscurations of 1090 and 1203 were thought by Chladni to be owing to the passage of meteoric masses between the Sun and Earth, causing an eclipse of that luminary.

Meteorites are now supposed to have a cosmical origin, and to belong to a group or annulus which the Earth encounters in her orbit. The obliquity of their paths in their descent to the Earth, and the explosions attendant on their fall, seem to favor that doctrine.

In 1606, Halley observed a fire-ball, which he pronounced to be of cosmical origin; but it was not till 1794 that Chladni recognised a connection between fire-balls and meteorites.

It is only when meteorites arrive within the limits of our atmosphere and ignite, that we have any knowledge of their existence; for they are only visible when they become luminous by ignition. They are by some supposed to be fragments of asteroids, or small bodies, of which there are probably myriads throughout our system, all revolving round the Sun as a common centre, and which are sometimes diverted from their orbits by some disturbing force. Portions of these asteroids may be attracted to other planets as well as to our Earth.

The analysis, by Mr. Faraday, of a very large meteorite found at Cape Colony, affords a view of the general nature of their constituents: Silica, 28·9; protoxide of iron, 33·22; magnesia, 19·2; alumina, 5·22; lime, 1·61; oxide of nickel, 0·82; sesquioxide of chromium, 0·7; sulphur, 4·24; water, 6·5. The average specific gravity of meteorites equals 3·0.

The falls of meteoric stones have been found, from numerous observations, to be much fewer in December and January than in June and July. If, therefore,

---

* Cosmos, vol. i. p. 121.

the meteorites belong to that system of asteroids which lie between Mars and Jupiter, the Earth would be more likely to meet with them when at her aphelion, or farthest distance from the Sun, which is in June and July, than in December, when she is nearest to the Sun.

Le Verrier has made a calculation which shows that the mean mass or system of the asteroids cannot exceed one-fourth of the mass of the Earth; and also that it is highly probable that the system of asteroids is at its perihelion when the Earth is at aphelion; consequently, the Earth is nearer to them at that period (June) than any other time of the year. This theory is favorable to the supposition that meteorites are outliers, or minute accompaniments, to the system of asteroids. Their specific gravity is supposed to be about the same as that of the asteroids. See *Am. Jour. Science and Arts*, Jan. 1855.

Zodiacal Light.

Note 52, Page 198.

The phenomenon of zodiacal light is not mentioned by any of the early writers, although it certainly could not have escaped the notice of the Arabian and Grecian astronomers.

An ancient Aztec MS. preserved in the Bibliothéque du Roi, at Paris, contains an account of a remarkable light which was visible for forty consecutive nights in the year 1509, and which Montezuma regarded as an omen of his downfall. This is now supposed to have been an unusually luminous zodiacal light, as it is recorded to have been seen in the immediate vicinity of the Sun when he was below the horizon.

This phenomenon was first observed in Europe by Childrey, in 1661, the description of which occurs in his *Britannia Baconica.* Dominic Cassini, in 1663, was, however, the first who investigated all the phenomena attendant on zodiacal light.

Humboldt observed the various intensities of this light in the tropical regions; he has seen it flicker and wane from a very strong to a pale light, and then suddenly shoot up again as bright as before.

A phenomenon, similar to the zodiacal light, if not identical with it, is described by John Christopher Sturmius, a German philosopher, who flourished during the last half of the seventeenth century. He called it *Heliocometes*, or comet of the Sun, because the light which he sometimes observed at sunset appeared like a large column of light attached to the Sun, like a tail to a comet.

The Rev. Geo. Jones, of the U. S. N., a member of the corps belonging to the Japan Expedition, has made numerous observations on the zodiacal light, showing that in that climate "it never fails to be seen when the Moon and clouds do not interfere." See *United States Exploring Expedition*, vol. v. p. 477.

Biot inferred that the zodiacal light might be in some way connected with the Earth. By experiments he found that it gave more heat than the tail of a comet.

When at the summer solstice, according to the observations of the Rev. Mr. Jones, the zodiacal light was visible from 11 till 1 in both horizons, with their apices approaching each other.

From the facts which he accumulated with regard to this singular phenomenon,

Mr. Jones concludes this light to be a *nebulous ring surrounding the Earth,* in which the meteors and even the meteorites may have their origin. Observations show there is a constant commotion within the ring itself, from which the nebulous matter half agglomerated in different parts of it may be thrown beyond its sphere, and fall to the Earth by its superior attraction.

Professor Peirce concurred with Mr. Jones in his theory, and Professor Gould thought that Mr. Jones's observations threw more light on the nature of zodiacal light than all before him.—*Proceedings of the American Association for the Advancement of Science,* August, 1855.

Origin of the Constellations.

NOTE 53, PAGE 200.

THOSE who have made Oriental literature their study are united in the opinion that the constellations were not grouped in reference to any resemblance certain collections of stars may have to the forms of animals or monsters, but that they were intended to indicate the successive returns of the seasons, and the various labors of the husbandman.

The zodiacal constellations, which are supposed to be of far more ancient origin than the northern or southern, appear to represent a picture of the whole year, considered in connection with the sunlight, vegetation, and agricultural labors. The names of the months in some countries of Egypt and the East, of which the celestial signs were the hieroglyphic expression, were given in accordance with the state of vegetation, &c. Even in modern times the French calendar under the Republic adopted the same plan; thus *Germinal* was blossom month, *Fructidor* was flower month, &c. The Germans in some districts call June the hay month, July, the harvest month, &c.

Various nations have claimed the honor of the construction of the constellations, especially the Chaldeans, the Egyptians, the Chinese, and the nations of India, all of whom assert that the science of astronomy had its origin with the founders of their several empires. Although the various groups of stars bear little or no resemblance to the figures in which they are included, yet the similarity of these configurations, as adopted by different nations, bespeaks a common origin. Thus the Chaldean, Egyptian, Indian, Arabic, and Grecian zodiacs are very similar to each other; and if it be true that the various divisions or signs were formed in reference to the position of the Sun and the employments of the agriculturist, the Egyptian origin is in some respects the most probable one.*

Still a difficulty presents itself, if we suppose the constellations of the zodiac to have been named by the Chaldeans, Egyptians, or Ethiopians, as the seasons in these countries do not coincide with the symbols. But if we follow the opinions of some Orientalists, and take the position of the heavens as it was about 15,000 years ago, the coincidence will be complete. In that case the zodiac would be a true representation of the heavens and of the seasons of Egypt at that epoch.

* Lucian assigns Ethiopia as the birthplace of astronomical science, from whence it descended to the Egyptians.—*Lucian, Astrol.* p. 985.

Hence it is inferred that the figures traced on our zodiac are not fanciful, designed at hazard and without any object, but that they are the natural symbols of the return of the different seasons among the people with whom they originated.

If we take the position of the sphere as it was at the epoch above mentioned, we shall find Capricorn to be the summer solstitial point, the reverse of which holds at present.* Capricorn is represented as amphibious, having the head of a goat and the tail of a fish; the next sign, Aquarius, is represented as a man pouring water from an urn, which finally forms a river; the third sign, Pisces, is composed of two fishes united by a cord. These three signs are symbolical of the situation of Egypt during the three months which follow the summer solstice; for it is well known that soon after that time the Nile inundates the country through which it flows, and does not completely recede until the autumnal equinox. Thus is the overflow of the Nile typified by the three signs, which evidently relate to water—namely, the goat with a fish's tail, the urn from which the river issues, and the fishes. A friend of the author's saw a small ancient vase in the possession of the Earl of Warwick, with an inscription on it, of which the following is a translation:

> "Wise ancients knew, when *Crater* rose to sight,
> Nile's fertile deluge had attained its height."

The greatest northern declination, or highest elevation of the Sun, is typified by the Goat, which always delights to browze on the summits of mountains or the peaks of the highest rocks.

The Earth is soon covered with rich pasturage after the water has retired, which is represented by the Ram, the chief or head of the flock. The commencement of agricultural labor is represented by the Bull, the sign the Sun occupied at that time of year at the period above mentioned. Manilius speaks of the Bull as an emblem of rural labor. The appearance of the grain above the ground on the following month is typified by the Twins, two very young children, or, according to some of the Oriental spheres, by two young goats.

The Sun next arrives at Cancer, which was, at the remote date above stated, the winter solstitial point; at which time he retraces his path, which is aptly typified by the retrograde movements of the Crab. One month after this the harvest is ripening for the sickle, which is represented by the Lion, as symbolical of the strength which vegetation has already acquired. According to Diodorus, the time between seed-time and harvest in Egypt is only about four months; so that the sign for the month of harvest would be Virgo, which is represented by a female with an ear of wheat in her hand, signifying the time of harvest. The Persians call this sign the "ear of wheat," from whence is derived *Spica*, the name of the principal star in this constellation. The sign of the Scales or Balance, which follows Virgo, announces as important an epoch in the astronomical year as that of the ear of wheat in the rural year. The Balance signifies the equality

---

* Father Kircher, a German Jesuit, and Professor of Hebrew and Mathematics, who died at Rome in 1680, was a man of great learning and untiring diligence. His favorite study was Egyptian hieroglyphics; and in a work on that subject gives the representation of an Egyptian Planisphere, which places Capricorn at the summer solstice.

of the days and nights—the equal division of light and darkness. This sign at that time answered to the *vernal* equinox. The supposition that the Balance was *originally* placed at the autumnal equinox becomes chimerical, when it is remembered that the science of astronomy had been known long before the asterisms of the Balance *could* answer to the autumnal equinox.

The Scorpion, being a venomous reptile, is emblematical of the sickly season. Sagittarius, the Archer, in some of the ancient zodiacs is only represented by a bow and arrow. As the arrow, which is just ready to leave the bow, is an emblem of swiftness, it represents the season of high winds.

In the Philosophical Transactions for 1772, there is a paper containing a communication from Nevil Maskelyne, then Astronomer Royal, in which there is a description, together with an engraving, of an Indian zodiac, in which Cancer is represented on the *south* and Capricorn on the *north* side* of the ceiling. The signs are the same, or nearly the same, as those now in use.

The foregoing is among the many conjectures which have been made with regard to the origin of the zodiacal constellations, and which, though highly ingenious and very plausible, is still open to objections.

As to the origin of the other asterisms, we have no reason to suppose it is entitled to as high antiquity as that of the zodiacal constellations, though Homer speaks of the Great Bear, Boötes, Orion, and Sirius. The Pleiades, Orion, Arcturus, and Sirius are mentioned by Hesiod. The three first are also spoken of in Holy Writ.

Sir John Herschel is of opinion that there was no object in thus naming the constellations. In treating of that subject, he says: "The constellations seem to have been almost purposely named and delineated to cause as much confusion and inconvenience as possible. Innumerable snakes twine through long and contorted areas of the heavens, where no memory can follow them; bears, lions, and fishes, large and small, northern and southern, confuse all nomenclature. A better system of constellations might have been a material help as an artificial memory."

But the present stellar arrangement, at least as regards the old forty-eight asterisms, is considered by some modern astronomers as highly useful for those who are not supplied with instruments for finding the places of the fixed stars. By means of this grouping into constellations, the eye becomes familiar with the principal stars of each group or family, and thereby aids the memory in retaining the places of others less conspicuous. "Those," says Smyth, "who would sweep away the constellations altogether, as incongruous absurdities or wicked pagan allusions, seem rather reckless about the consequences of such a measure on astronomical history, chronology, and extra-observatorial practice."

It is evident from what has been said that the origin of the constellations, especially those of the zodiac, is wrapped in the obscurity of the most remote antiquity, from which it would now be impossible to wrest it.

---

* The sketch is by Mr. J. Call, who copied it from a pagoda near Cape Comorin, in India; a similar one was found by the same author on the ceiling of a temple near Mindurah.—*Phil. Trans.* vol. lxii p. 353; also *Mrs. Somerville's Phys. Sci.* p. 83, &c.

The Pole Star four thousand years ago.

NOTE 54, PAGE 217.

THE following, from Sir John Herschel's Outlines of Astronomy, shows the changes in the celestial pole in four thousand years:

"At the date of the erection of the Great Pyramid of Gizeh, which precedes the present epoch by nearly 4000 years, the longitudes of all the stars were less by 55° 45′ than at present. Calculating, from this datum, the place of the pole of the heavens among the stars, it will be found to fall near α Draconis; its distance from that star being 3° 44′ 25″. This being the most conspicuous star in the immediate neighborhood, was therefore the Pole Star at that epoch. The latitude of Gizeh being just 30° north, and consequently the altitude of the North Pole there also 30°, it follows that the star in question must have had, at its lower culmination at Gizeh, an altitude of 26° 15′ 35″. Now it is a remarkable fact, that of the nine pyramids still existing at Gizeh, six (including all the largest) have the narrow passages, by which alone they can be entered, (all which open out on the northern faces of their respective pyramids,) inclined to the horizon downwards at an angle as follows:

1. Pyramid of Cheops	26°	41′
2. " " Cephren	25	55
3. " " Mycerinus	26	2
4.	27	0
5.	27	12
9.	28	0
Mean	26°	47′

At the bottom of every one of these passages, therefore, the Pole Star must have been visible at its lower culmination, a circumstance which can hardly be supposed to have been unintentional, and was doubtless connected (perhaps superstitiously) with the astronomical observations of that star, of whose proximity to the pole at the epoch of the erection of these wonderful structures we are thus furnished with a monumental record of the most imperishable nature."—*Hers. Ast.* p. 174.

Great Nebula of Canes Venatici.

NOTE 55, PAGE 219.

THIS wonderful object was discovered in the year 1772, by Messier, a noted French astronomer, and described by him as faint *double* nebulæ, whose centres were 4′ 35″ apart, but with the bodies in contact.

"Supposing it," says Sir John Herschel, "to consist of stars, the appearance it would present to a spectator placed on a planet attendant on one of them, eccentrically situated towards the *north preceding* quarter of the central mass, would be exactly similar to that of our Milky Way, traversing, in a manner precisely analogous, the firmament of large stars, into which the central cluster would be seen projected, and (owing to its greater distance) appearing, like it, to consist of stars much smaller than those in other parts of the heavens. Can it then be that we have here a brother system bearing a real physical resemblance to our own?"

Since Sir John Herschel formed his catalogue of northern stars, Lord Rosse's great telescope has revealed this nebula to be spiral, with two nuclei. But still some astronomers trace a resemblance between it and the Milky Way, which is also supposed to be spiral.* From the above, it will be seen that the modern improvements in telescopes reveal more and more the wonderful structure of the universe, which, before their invention, had been a "sealed book." By their aid we are permitted to obtain a glimpse of that amazing display of the Omnipotent energy and power so fully manifested in the order and harmony of the innumerable host composing the stellar universe. "We thus observe," says Lord Rosse, "that with each successive increase of optical power, the structure has become more complicated, and more unlike any thing which we could picture to ourselves as the result of any form of dynamical law of which we find a counterpart in our system. The connection of the companion with the greater nebula, of which there is not the least doubt, and in the way represented in the sketch, adds, as it appears to me, if possible, to the difficulty of forming any hypothesis. That such a system should exist without internal movement, seems to be in the highest degree improbable; we may possibly aid our conceptions, by coupling with the idea of motion that of a resisting medium; but we cannot regard such a system, in any way, as a case of mere statical equilibrium."—*Phil. Trans.* 1850, p. 504.

---

* See The Origin, &c. of Clusters, Stars, and Nebulæ, by Professor Stephen Alexander, American Astronomical Journal, vol. ii. p. 101.

ASTRONOMICAL DICTIONARY.

Abbreviations.—Alt., Altitude; A. M. *Ante Meridian,* before noon, or *Anno Mundi,* the year of the world; App., Apparent; Æ., R. A., or *a*, *Right Ascension;* B. A. C. *British Association Catalogue;* Barom., *Barometer;* B. Z., Bessel's Zones; Cat., Catalogue; Circum., *Circumference;* Collim., *Collimator;* D., *Direct;* Dec. or d., *Declination;* Deg., *Degree;* Diam., *Diameter;* Diff., *Difference;* Dist., *Distance;* Ep., *Epoch;* Eq., *Equator,* or *Equinoctial;* Exter., *External;* G. M. T., *Greenwich Mean Time;* Hor. Eq. Par., Horizontal Equatorial Parallax; Incl., *Inclination;* Inter., *Internal;* M., Meridian, or Meridies, *Midday, noon;* Mag., *Magnitude;* Micr., *Micrometer;* Min. or m., *Minute;* M. T., Mean Time; N. L., *North Latitude;* N., *North;* Neb., *Nebula;* N. P. D., *North Polar Distance;* n. p., *north preceding;* n. f., *north following;* N. S., *New Style;* Obs., *Observation;* O. S., *Old Style;* Par., *Parallax;* Pos., *Position;* Prec., *Precession;* R., *Retrograde;* Rad., *Radius;* Rev., *Revolution;* S., *South;* s. f., *south following;* s. p., *south preceding;* S. L., *South Latitude;* Sec. or s., Second of time; Supra Polum, *above the pole;* Sub polo., *below the pole;* Tang., *Tangent;* Thermom., *Thermometer.*

The following are found in almanacs: A. com., *Autumn commences;* Ald., *Aldebaran;* Alg., *Algenib;* Alt., *Altair;* Ant., *Antares;* Arc., *Arcturus;* Ari., *Arietis;* Cap., *Capella;* Cas., *Castor;* Decl., *Declination;* D. M., *Days of the Month;* D. W., *Days of the Week;* e., *elongation;* E., *East;* Fom., Fomalhaut; gr't, *greatest;* gt. elong. or grèat. eg. W., *greatest Western elongation;* great. bril., *greatest brilliancy;* H., *Hour;* H. L. N., *Heliocentric Latitude North;* Inf., *Inferior;* inv., *invisible;* M., Morning, Month, or Minute; Mag., *Magnitude;* Mar., *Markab;* Pro., *Procyon;* Reg., *Regulus;* S. or ☉ sl., *Sun slow;* S. ☉ fst., *Sun fast;* S. com., *Summer commences;* Sir., *Sirius;* sup., *superior;* W., Week or West; W. com., *Winter commences;* 7*s., *Pleiades.*

The following are the abbreviations used in catalogues for the names of observers:

A. Argelander.
B. Baily.
B. Brisbane.
Br. Briosche.
D. Dawes.
△. Dunlop.
♅. Herschel, Senr.
H. Herschel, Junr.
h., followed by a number, refers to Sir J. Herschel's Catalogue of Northern Stars.
H. and S. Herschel and South.
M. Messier.
P. Piazzi.
S. South.
Σ. Struve.
Sm. Smyth.
T. Taylor.

The following abbreviations are used by Sir John Herschel in his catalogues:

B. denotes bright.
b. — brighter.
br. — broad.
c. — considerably.
Cl. or cl. — cluster.
comp. — compressed.
D. — Double.
d. — diameter, distance.
E. — extended, elongated, elliptic.

e. denotes extremely.
ee. — excessively.
F. — faint.
f. — following.
fig. — figure.
g. — gradually.
i. or irr. — irregular.
f. — sweep.
L. — large.
l. — long or little.
M. — in the middle.
m. — much.
N. — nebula.
neb. — nebulous.
n. — north.
p. — pretty, preceding.
pos. — angle of position.
R. — round.
r. — resolvable.
S. — small.
s. — south, suddenly.
st. — stars.
sc. — scattered
v. — very.
vv. — very exceedingly.

Pisc. Aust., *Pisces Australis;* Cor. Aust., *Corona Australis;* Triang. Austr., *Triangulum Australis;* Cat., *Catalogue;* Atmosp., *Atmosphere.*

Aberration, (*aberro,* to wander from.)—The apparent displacement of the heavenly bodies caused by the velocity of light, and the Earth's annual motion in her orbit.

Aberration, Constant of.—During the interval which light requires to travel from the Sun to the Earth, the latter body has moved, with her average velocity, through an arc of 20·45″, which is therefore the amount of displacement in the Sun's longitude arising from the progressive motion of light; this is called the *Constant of Aberration.*

Aberration, Chromatic.—The unequal refrangibility of the rays composing white light, producing prismatic colors around the image of the object when viewed through a lens.

Aberration, Diurnal.—A phenomenon caused by the movement of light combined with the rotation of the Earth on its axis.—*Loomis.*

Aberration of the Fixed Stars.—The apparent annual motion of the fixed stars, produced by the velocity of light combined with the real motion of the Earth in its orbit, which causes each star apparently to describe a small ellipse, the centre of which is the true place of the star.

Aberration of Planets and Comets.—An apparent displacement of their positions, arising from the progressive motion of light, whereby we always see them *behind* their true places in the heavens at the moment of observation.

Aberration, Spherical.—The deviation of the rays of light from the true focus of a curved lens, producing a confused image of the object.

Accelerated Motion.—Motion which receives fresh accessions of velocity.

Accelerating Force.—The force that accelerates the velocity of bodies. It is expressed by the quotient arising from the motive or absolute force divided by the mass or weight of the body that is moved.—*Hutton.*

Acceleration, (*accelero,* to hasten.)—The increase of velocity in a moving body; the state of being quickened in motion.

Acceleration of the Fixed Stars.—The time which the stars anticipate the Sun in a mean diurnal revolution, which is 3*m.* 55·9*s.* of mean time. In other words, it is the difference of time between a sidereal and a solar day.

Acceleration of the Moon.—A secular variation in the Moon's motion, amounting to about 11″ in a century, occasioned by the variation in the eccentricity in the Earth's orbit.

Accidental Colors.—Those colors which depend upon the affections of the eye, in contradistinction to such as belong to the light itself. These are also called *complementary colors.*

Achernar.—A star of the first magnitude in the constellation Eridanus.

Achromatic, (*a,* deprived of, and χρῶμα, *color.*)—Without color. A term first used by M. de Lalande to denote telescopes contrived to remedy aberrations and colors.

Achronical, (*αχρος, the extremity,* and *νοξ, night.*)—A star is said to rise or set achronically when it rises or sets opposite to the Sun.

Acolyte.—An attendant star, a companion star.

Acrux.—A name given to the principal star in the Southern Cross, known as α Crucis.

Acubens.—A star of the fourth magnitude in the constellation Cancer, known also as α Cancri.

Acute Angle.—See ANGLE.

Acute-angled Triangle.—A triangle having all its angles acute.

Acute Cone.—A cone in which the vertical angle of the meridian triangle is less than 90°.

Adara.—The name given to ε Canis Majoris, a star in the constellation Canis Major.

Adjacent Angles.—See ANGLE.

Adjustment, (*ad,* to, and *justus,* just.)—The operation of bringing all the parts of an instrument into their proper relative positions.

Adjustment, Errors of.—Errors arising from an instrument not being properly placed, and from its movable parts not being properly disposed.

Aerolite, (*αηρ, the air,* and *λιθος,* a *stone.*)—A name given to those mineral substances which sometimes fall from the upper region of our atmosphere. They are also known by the names of meteoric stones, fire-balls, bolides, shooting-stars, meteorolithes, &c.

Afeichus.—An Arabic name for the constellation Ophiuchus.

Age.—Used in chronology for a century.

Age of the Moon.—The distance from her conjunction, or the number of days elapsed since the last new moon.

Agena.—Another name for β Centauri, a star in the constellation Centaurus.

Ain-al-thaur.—Another name for *Aldebaran,* which see.

Air.—See ATMOSPHERE.

Akrab.—A name given to β Scorpii, a star of the second magnitude in the constellation Scorpio. It is sometimes called *Graffias.*

Albireo.—One of the chief stars in the constellation Cygnus, known also as β Cygni.

Al Chiba.—An Arabic name for the star α Corvi, in the constellation Corvus.

Alcor.—A small star in Ursa Major, known as ρ Ursæ Majoris.

Alcyone.—The principal star of the Pleiades, called η Tauri.

Aldebaran.—An Arabic name for a fixed star of the first magnitude, situated in the constellation *Taurus.* It is popularly called the *Bull's Eye.*

Alderamin.—A star in the constellation Cepheus, also known α Cephei.

Aldhiba.—A star in the constellation Draco, and which is also called ι Draconis.

Algenib.—A star in the constellation Pegasus, known also as γ Pegasi. The name of Algenib is also sometimes given to α Persei, a star in the constellation Perseus.

Algieba.—A star in the constellation Leo, also known as γ Leonis.

Algol.—This star, known as β Persei, is variable. Its period is rather less than three days.

Algorab.—A bright star in the constellation Corvus, called also δ Corvi.

Alhaid.—See BENETNASCH.

Alidad or Alhidade.—An Arabic name for the index or ruler movable about the centre of an astrolabe.

Alidade Level.—A spirit-level attached to the bar and small circle belonging to the instrument called the meridian circle.

Alioth.—A star in the constellation Ursa Major, also called ε Ursæ Majoris.

Alkalurops.—A triple star in the constellation Boötes, commonly known as μ Boötis.

Alkes.—A name given to a star in the constellation Crater, also called α Crateris.

Almacantais, (from the Arabic *Almocantharat.*)—A name for the circles of altitude. These are circles parallel to the horizon, serving to show the height of the Sun, Moon, or stars.

Almacantar Staff.—An instrument having an arc of about 15°, used for observing the Sun or a star when near the horizon, to find the amplitude or the variation of the needle.

Almagest.—A collection of problems in

geometry, and observations in astronomy, compiled by Ptolemy.

Almak.—A star in the constellation Andromeda, called γ Andromedæ.

Almanac.—According to Golius, it is derived from the Arabic particle *al*, and *manah*, a reckoning. Scaliger derives it from the Arabic particle *al*, *μαναχος, the course of the months;* but Vestigan ascribes it to Saxon origin, believing it to be from the compound Saxon word Almon-aht—that is, All-moon-heed, or an account of every moon, which the Saxons are said to have kept very carefully. An almanac is a table or calendar, containing an account of the months, weeks, &c. of the year, and also of the festivals.

Almeisam.—The Arabic name for the star γ Geminorum.

Al-Mirzam.—See Gomeisa.

Almucantar.—See Almacantar.

Alnilham.—A star of the second magnitude in Orion's Belt, also known as ε Orionis.

Alnitak.—A star in the belt of Orion, generally called ζ Orionis.

Alphard.—A name given to a star in the constellation Hydra, also known as α Hydræ or *Cor Hydræ.*

Alphecca or **Gemma.**—The brightest star in the constellation Corona Borealis, also known as α Coronæ Borealis.

Alpheratz or **Sirrah.**—A star in Andromeda, also called α Andromedæ. This star is the north-eastern boundary of the square of Pegasus.

Alphirk.—This star, called β Cephei, is of the third magnitude in the constellation Cepheus.

Alphonsine Tables.—See Tables.

Alrucaba.—The same as *Polar Star*, which see.

Alshain.—Another name for the star β Aquilæ, in the constellation Aquila.

Altair.—A star of the first magnitude in the constellation Aquila, called also α Aquilæ.

Altimeter, (*altus*, high, and *μετρον, measure.*)—An instrument for measuring altitudes; as a quadrant, sextant, or theodolite.

Altimetry.—The art of measuring altitudes.

Altitude, (from *altitudo*, height.)—The height of an object above the horizon; or, in other words, the arc of a vertical circle contained between the centre of the object and the horizon.

Altitude and Azimuth Instrument.—An instrument used to find the place of a heavenly body in altitude and azimuth.

Altitude, Apparent.—The distance of a heavenly body from the apparent or sensible horizon.

Altitude Instrument.—The equal-altitude instrument is used to observe a celestial object when it has the same or an equal altitude on both sides of the meridian. It is useful in adjusting clocks.

Altitude, Meridian.—See Meridian Altitude.

Altitude of the Equator.—The angle or arc of the meridian intercepted between the horizon and the equator. It is equal to the co-latitude of the place.

Altitude or **Elevation of the Pole.**—An arc of the meridian intercepted between the horizon and the pole of the heavens; it is equal to the latitude of the place.

Altitude of the Tropics.—Otherwise called the *solstitial altitude of the Sun;* his meridian altitude when in the solstitial points.

Altitude, True.—The distance of a celestial body from the real or rational horizon. The correction of the apparent altitude on account of refraction and parallax.

Aludra.—A name applied to the star η Canis Majoris, in the constellation Canis Major.

Alwaid.—A star in the constellation Draco, known also as β Draconis.

Alya.—Another name for a star in the constellation Serpens, known also as θ Serpentis.

Amorphotæ.—Unformed stars, or those stars which are not considered as included in any constellation.

Amphiscii, (*αμφι, on both sides*, and *σκια, a shadow.*)—The inhabitants of the torrid zone are so called, because one-half the year their shadows point north, and the other half south.

Amphitrite.—The twenty-ninth asteroid.

It was discovered by Marth, March 2, 1854.

Amplitude, (*amplitudo*, extent.)—An arc of the horizon contained between the centre of the object when rising or setting and the east and west points of the horizon. It is the distance which a heavenly body rises from the east and sets from the west. Amplitude is *ortive* or *eastern* when the star is rising, and *occiduous* or *western* when it is setting.

Analemma.—A narrow strip painted on the globe, the length of which is equal to the breadth of the torrid zone. It is di-divided into months, and days of the month, corresponding to the Sun's declination for every day in the year. It is also divided into two parts; the right-hand one begins at the winter solstice, or 22d of December, and is reckoned towards the summer solstice, or the 21st of June, where the left-hand part begins, which is reckoned in a similar manner towards the winter solstice. By the analemma the *equation of time* is shown.

Anachronism, (*ἀνὰ, higher*, and *φρόνος, time.*) —An error in the computation of time, whereby an event is placed earlier than it really occurred.

Ancha.—A name given to the star θ Aquarii, in the constellation Aquarius.

Andromeda.—A constellation in the northern hemisphere, so named by the Greeks in honor of Andromeda, the daughter of Cepheus. The right ascension and declination of the middle of the constellation are R. A. 0*h.* 56*m.*, Dec. 32° N.

Angle, (*angulus*, a corner.)—The inclination or opening of two lines, having different directions, and meeting in a point.

Angle, Acute, (*acutus*, sharp-pointed.)—An angle less than a right angle, or which does not subtend 90°.

Angle of Commutation.—The angle at the Sun formed by two lines, the one drawn from the Earth, and the other from the place of a planet reduced to the ecliptic, both meeting in the Sun's centre. It is the difference between the Sun's longitude and the heliocentric longitude of a planet.

Angle of Contact.—See Contact.

Angle of Elongation.—The angular distance of any planet from the Sun with respect to the Earth; or the difference between the Sun's place and the geocentric place of a planet.

Angle of Eccentricity.—The angle whose sine is equal to the eccentricity of an orbit. It is the angle formed at the extremity of the minor axis of the ellipse by lines drawn to the centre and one of its foci, and is usually denoted by the Greek letter ϕ.

Angle, Exterior.—In a polygon, the angle included between any side and the prolongation of the adjacent one. In a triangle any exterior angle is equal to the sum of the two interior opposite ones. In any right-lined figure the sum of all the exterior angles is always equal to four right angles.

Angle of Incidence.—That made by the line of direction of an impinging body at the point of impact.

Angle of Longitude.—The angle which the circle of a star's longitude makes with the meridian at the pole of the ecliptic.

Angle, Obtuse.—An angle greater than a right angle. It therefore contains more than 90°, and less than 180°.

Angle of Position.—In a binary system of stars, it is the angle which the meridian, or a parallel to the equator, makes with the line joining the two stars. It is the angle formed by a line joining the two stars, with the meridian passing through the larger one, and is reckoned from 0° to 360°, beginning at the north point, and counting round by the east.

Angle of Reflection.—That made by the line of direction of a reflected body at the point of impact.

Angle, Right.—An angle formed by the meeting of two straight lines, one of which is perpendicular to the other. A right angle contains 90°, or the quarter of a circle.

Angle of Right Ascension.—The angle which the circle of the star's right ascension makes with the meridian at the pole of the equator.

Angle of Situation.—The angle made at a star by arcs passing through the zenith and pole respectively. It is also termed the *parallactic angle.*

Angle, Spherical.—An angle formed on the surface of a sphere by the intersection of two circles, or the inclination of the planes of those circles.

Angle of the Vertical.—The difference between the geographical and geocentric latitudes of a place. It is zero at the equator, and increases up to the 45th degree of latitude, when it amounts to 11′ 30″, and thence diminishes to zero again at the pole.

Angle of Vision.—The angle included between two rays of light drawn to the eye from the extreme points of an object.

Angles, Adjacent.—Those angles in the same plane which have one side in common, and their other sides in the prolongation of the same straight line.

Angles, Contiguous.—Those angles which have the same vertex and a side common to both, but the other sides not in the same straight line.

Angular Motion.—The motion of a body which moves circularly about a point; or the variation in the angle described by a line or radius connecting a body with the centre about which it moves.

Angular Velocity.—The swiftness with which a body revolves; or, the speed with which the surface of the Earth performs its daily rotation about its axis. As applied to a double star, it is the rate of motion of one star round the other.

Annual.—Yearly, returning or ending with the year.

Annual Argument of the Moon's Apogee.—See Argument.

Annual Equation.—An inequality caused by a variation in the angular motion of the Moon, which becomes slower as the Earth and Moon are approaching the Sun, and accelerates as they recede from him.

Annual Parallax.—The angle under which the diameter of the Earth's orbit would appear if viewed from a distant planet or a fixed star.

Annual Revolution.—The yearly course of the Earth round the Sun, producing the phenomena of the seasons.

Annual Variation.—The change produced in the right ascension or declination of a star by the precession of the equinoxes and proper motion of the star combined.

Annular, (*annulus,* a ring.)—Having the form of a ring.

Annular Eclipse.—The eclipse of the whole orb of the Sun, except a ring or annulus, which appears round the border or edge.

Anomalistic Revolution of the Moon.—The passage of the Moon from perigee to perigee, or from apogee to apogee.

Anomalistic Year.—The interval of time between two consecutive returns of the Earth to her perihelion or aphelion; or, the time in which the Earth or a planet passes through its orbit with regard to its line of apsides.

Anomaly, (*ἀνώμαλια, irregularity.*)—The angular distance of a planet from aphelion or apogee; that is, the angle formed by the line of the apses, and another line drawn through the planet.

Anomaly, Eccentric.—An auxiliary angle employed to abridge the calculations connected with the motion of a planet or comet in an elliptic orbit. If a circle be drawn, having its centre coincident with that of the ellipse, and a diameter equal to the transverse axis of the latter, and if from this axis a perpendicular be drawn through the true place of the body in the ellipse to meet the circumference of the circle, then the eccentric anomaly will be the angle formed by a line drawn from the point where the perpendicular meets the circle, to the centre, with the longer diameter of the ellipse.—*Hind.*

Anomaly, Mean.—The angular distance of a planet or comet from perihelion or aphelion, supposing it to have moved with its mean velocity.

Anomaly, True or Equated.—The angular distance of a planet or comet from the perihelion or aphelion.

Ansæ or Anses, (*ansæ,* handles.)—The apparently prominent parts of the ring of the planet Saturn.

Anser Americanus.—Another name for *Toucana*, which see.

Antarctic Circle.—An imaginary, small circle, parallel to the equator, and 23° 28′ from the South Pole.

Antartic Pole, (*αντι, against* or *opposite to,* and *ἄρκτος, a bear.*)—The southern extremity of the Earth's axis.

Antares.—The principal star in the constellation Scorpio, sometimes called *Cor Scorpionis, Calbalacrab,* and *α Scorpii.*

Antecedentia.—A term signifying a retrograde motion of a planet; that is, contrary to the order of the signs.

Antemeridian, (*ante,* before, and *meridies,* noon.)—The time before noon. Abbreviated thus, A. M.

Anthelion, (*αντι,* opposite, and *ηλιος,* the Sun.)—In the northern portions of our globe the Sun and Moon frequently appear surrounded by *halos* or colored circles. When a horizontal white circle intersects these halos, bright spots, resembling the Sun, appear near their intersection. In the horizontal circle there are often other bright spots, nearly opposite to the Sun; these are called *anthelia.*

Antimeter.—An instrument used for the accurate measurement of angles.

Antinous.—A northern constellation, generally reckoned as part of the constellation Aquila. Its R. A. is 19*h.* 28*m.*, and its Dec. 0° 0′.

Antipodes, (*ἀντὶ, opposite to,* and *ποδος, the foot.*)—The inhabitants of two places on the Earth which lie immediately opposite to each other, or where they walk feet to feet.

Antiscians, (*ἀντὶ, opposite to,* and *σχία, a shadow.*)—Those who, living in opposite hemispheres, have their shadows at noon directly opposite to each other.

Antlia Pneumatica.—One of the southern constellations, introduced by Lacaille. Its R. A. is 10*h.* 0*m.*, and Dec. 35° 0′ S.

Antœci, (*ἀντὶ, opposite to,* and *οἶχος, a house.*)—Those inhabitants of the Earth who live under the same meridian east or west, but under opposite parallels of latitude north or south.

Antolycus.—A crater or cavity in the lunar surface, seen only through the telescope.

Apastron, (*ἀπὸ, from,* and *αςτρον, a star.*)—That point in the orbit of a double star which is farthest from its primary.

Aperture.—That portion of the object-glass of a telescope through which objects may be viewed, which is generally rather less than the tube of the instrument. Also, the opening of the tube or cylinder in which the object-glass is inserted.

Apex.—The summit or highest point of any thing; the vertex. The *apex* of a cone is the highest point above the base.

Aphelion, (*ἀπὸ, from,* and *ἥλιος, the Sun.*)—That point in the orbit of a planet or comet which is most distant from the Sun.

Aplanatic, (*a, deprived of,* and *πλάνη, error.*)—Void of error. A term applied to those optical instruments in which the spherical and chromatic aberrations are corrected.

Apogee, (*ἀπὸ, from,* and *γη, the Earth.*)—That point of the Moon's orbit farthest from the Earth.

Apogean Tides.—Those neap tides which occur soon after the Moon passes her apogee.

Apparent, (*appareo,* to appear.)—A term applied to things as they appear to the eye, in distinction from what they really are.

Apparent Conjunction.—The situation of two heavenly bodies being such that a right line, supposed to be drawn through their centres, would pass through the eye of a spectator, and not through the centre of the Earth.

Apparent Diameter or Magnitude.—The angle which the heavenly bodies subtend at the eye.

Apparent Distance.—The distance which we judge an object to be when seen from afar: thus all the heavenly bodies appear at the same distance from us, although they are situated many millions of miles asunder.

Apparent Equinox.—The position of the equinox as affected by nutation.

Apparent Horizon.—The circle which bounds our view on all sides; the sensible horizon.

Apparent Motion.—The motion of the

heavenly bodies as seen from our globe; or that motion which we see in a distant body which is moving or at rest, while the eye is either at rest or in motion.

Apparent Noon.—The time when the Sun comes to the meridian—viz., 12 o'clock, as shown by a correct sundial.

Apparent Obliquity.—The inclination of the equinoctial to the ecliptic, calculated with nutation.

Apparent Place.—That point where the centre of a heavenly body appears when viewed from the surface of the Earth.

Apparent Sidereal Day.—See SIDEREAL DAY.

Apparent Sidereal Time.—Time measured by the hour-angle of the apparent equinox.

Apparent Solar Day.—The time elapsed from 12 o'clock at noon on any day till 12 o'clock at noon on the next day, as shown by a correct sundial.

Apparent Time.—The measure of any duration rendered sensible by means of motion.

Apparent Zenith.—See ZENITH.

Apennines.—A chain of lunar peaks visible through the telescope.

Appulse, (*appello*, to drive to.)—The near approach of two heavenly bodies so as to be seen at the same time in the field of the telescope.

April.—The fourth month in the year, and the second from the vernal equinox. This word is derived from *aperio, to open;* because the Earth in this month opens her bosom for the production of plants.

Apsides or **Apses,** (*ἁψίς, a connection.*)—The extremities of the major axis of an orbit; that is, the point which a planet occupies at its greatest and least distances from the Sun; also those points at which a satellite is at its greatest and least distances from its primary. See LINE OF APSIDES.

Apsis, Higher.—That point in the orbit of the Earth or of a planet which is farthest from the Sun; its aphelion.

Apsis, Lower.—That point in the orbit of the Earth or of a planet which is nearest to the Sun; its perihelion.

Apus vel Avis Indica.—A southern constellation, the middle of which is R. A. 16*h.* 44*m.*, Dec. 73° 0′ S.

Aquarius.—The eleventh sign in the zodiac, and is marked thus ♒. R. A. 22*h.* 20*m.*, Dec. 14° 0′ S.

Aquila.—A northern constellation. R. A. 19*h.* 40*m.*, Dec. 10° 0′ N.

Ara.—A constellation in the southern hemisphere, a little to the south-east of Scorpio. R. A. 17*h.* 0*m.*, Dec. 55° 0′ S.

Aramech.—Another name for *Arcturus.*

Arc, (*arcus*, a bow.)—A part of any curved line, as of a circle, ellipse, &c.

Arc of Direction or Progression.—That arc which a planet appears to describe when its motion is direct or progressive.

Arc, Diurnal.—That part of a circle parallel to the equator, described by the Sun from his rising to his setting.

Arc, Nocturnal.—That part of a circle parallel to the equator, described by the Sun or a star from setting to rising.

Arc of Retrogradation.—The arc of the ecliptic described while a planet is retrograde, or moves contrary to the signs; that is, from east to west.

Archimedes.—A spot on the surface of the Moon visible by the aid of the telescope.

Arctic Circle, (*αρκτος, a bear;* because the constellation of the Great Bear is in its vicinity.)—One of the lesser circles of the globe, at the distance of 23° 28′ from the North Pole. It is also called the North Polar Circle.

Arctic Pole.—The northern extremity of the Earth's axis.

Arctophylax, (bear-keeper.)—A name given by the ancients to the constellation Boötes.

Arcturus.—A star of the first magnitude in the constellation Boötes. R. A. 14*h.* 8*m.*, Dec. 20° N.

Area.—Surface, superficial extent.

Argo Navis.—A southern constellation. R. A. 7*h.* 44*m.*, Dec. 50° S. As this constellation is unusually large, Sir John Herschel divided it into four parts—viz., *Carina*, the keel; *Puppis*, the stern; *Vela*, the sails; and *Argo Navis*, the hull. Some make another division—*Malus*, the mast.

Argument.—An arc given, by which another arc is found proportional to it.

Argument, Annual of the Moon's Apogee.—The distance of the Sun's place from the Moon's apogee; that is, an arc of the ecliptic comprised between these two places.

Argument of Latitude or **Argument of Inclination.**—The arc of a planet's orbit intercepted between the ascending node and the place of the planet from the Sun, numbered according to the succession of the signs.

Argument of Latitude, Menstrual.—The distance of the Moon's true place from the Sun's true place.

Arided.—A bright star in the constellation Cygnus, also called α Cygni.

Ariel.—A name given by Sir John Herschel to the first satellite of Uranus.

Aries.—The first of the twelve signs of the zodiac, and is marked thus ♈, in imitation of a ram's head. The first point of Aries is the origin from which the right ascensions of the heavenly bodies are reckoned upon the equator, and their longitudes upon the ecliptic.

Arietis.—The chief star in the constellation Aries; it is also called α Arietis, and by the Arabs was called *Hamal.*

Aristarchus.—A bright spot or prominent point on the surface of the Moon, as seen through a telescope.

Aristillus.—One of the lunar craters, visible by means of a telescope.

Aristotle.—A lunar inequality made visible by the telescope.

Armillary Sphere, (*armilla,* a bracelet.)—It is an instrument composed of a number of circles of metal, wood, or paper, representing the several circles of the sphere, and which assists in the conception of the disposition and motions of the heavenly bodies.

Arneb.—A name applied to a star in the constellation Lepus, also known as α Leporis.

Arrakis.—Another name for a star in the constellation Draco; it is also called μ Draconis.

Ascending.—A term used to indicate the rising of a heavenly body or point of the heavens above the horizon.

Ascending Constellations.—Those constellations through which the planets ascend northwardly.

Ascending Latitude.—The latitude of a planet when going north.

Ascending Node.—That point in a planet's orbit where it intersects the ecliptic proceeding northward. It is marked thus ☊.

Ascending Signs.—Those signs of the zodiac from the Tropic of Capricorn to that of Cancer are called the ascending signs. Also, those signs which are eastward of the meridian, and by the diurnal rotation of the Earth are approaching the zenith.

Ascension.—See Right and Oblique.

Ascension of the Midheaven.—The right ascension of that point of the equinoctial which is on the meridian.

Ascensional Difference.—The difference between right and oblique ascension of the same point on the surface of the sphere. It is the time the Sun rises or sets before or after six o'clock.

Ascii, (from ασκιος, *without shadow.*)—This name is applied to the inhabitants of the torrid zone, who twice a year have the Sun in their zenith at noon, and then have no shadow.

Asellus Australis.—A star in the constellation Cancer, also called δ Cancri.

Asellus Borealis.—A star in the constellation Cancer, known as γ Cancri.

Ashtaroth.—A name given by the ancients to the star α Coronæ Borealis.

Asmidiske.—A name given to the star ξ, in the constellation Argo Navis.

Aspect.—The situation of the stars or planets with regard to each other. They are as follows:

Name.	Character.	Distance.
Conjunction,	☌	0°
Sextile,	⚹	60°
Quartile,	□	90°
Trine,	△	120°
Opposition,	☍	180°

Aspidiske.—A name given by Ptolemy to the star ι Argo Navis.

Asterion et Chara.—See Canes Venatici.

Asterism.—A constellation; a group or collection of stars.

Asteroids or **Planetoids.**—This name was

given by Herschel to the small planets which revolve between the orbits of Mars and Jupiter. They are sometimes called the *ultra-zodiacal* planets.

Asterope.—A name given to one of the Pleiades.

Astral.—Relating to the stars.

Astrea.—The fifth asteroid; it was discovered by Hencke, December 8, 1845.

Astrognosy.—The science of the stars, or knowledge of their magnitudes, situations, &c.

Astrography, (*αστρον, a star,* and *γράφω, to write.*)—A description of the stars.

Astrolabe, (*ἀστρον, a star,* and *λαβειν, to take.*)—A system or assemblage of the several circles of the sphere in their proper order and situation with respect to each other. It was first made by Hipparchus, at Alexandria, in Egypt, and was afterwards modified by Ptolemy; so that the whole was reduced to a plane surface, which he called a *planisphere.* It was formerly used for taking observations at sea.

Astrolithology, (*αστρον, a star,* and *λιθος, a stone.*)—That branch of science pertaining to meteoric stones or meteorites.

Astrometer, (*αστρον, a star,* and *μετρον, a measure.*)—An instrument used to compare the intensities of the light of different stars; one who measures the light of the stars.

Astrometry.—The numerical expression of the apparent magnitudes of the fixed stars.

Astronomical Characters.—Those characters used in astronomy. See CHARACTERS.

Astronomical Horizon.—The same as Rational Horizon, which see.

Astronomical Hours.—Those hours which are reckoned from noon, or midday of one day, to noon of the following day, in a continued series of twenty-four.

Astronomical or **Natural Day.**—The time which elapses from noon to noon, which consists of twenty-four hours.

Astronomical Observations.—Those observations of the heavenly bodies made by astronomers in order to ascertain their forms, appearances, motions, &c.

Astronomical Place.—The longitude or place of a body in the ecliptic, reckoned from the first point of Aries, according to the order of the signs.

Astronomical Tables.—See TABLES.

Astronomical Telescope.—A telescope used only in astronomical observations.

Astronomy, (*ἀστρον, a star,* and *νομος, a law.*) The science which treats of the heavenly bodies and the laws by which they are governed.

Astroscope, (*αστρον, a star,* and *σκοπεω, to view.*)—A kind of astronomical instrument composed of telescopes, invented in 1698 by William Shukhard, Professor of Mathematics at Tubingen. Also, an instrument composed of two cones, having the constellations delineated on their surfaces: not now used.

Asymptote, (*α, deprived of,* and *συμπιπτω, to meet.*)—A name for lines which continually approach each other, but which, if infinitely produced, can never meet.

Atik.—A star in the constellation Perseus, called also *o* Pegasi.

Atlantides.—Another name for the Pleiades.

Atmosphere, (*ατμος, vapor,* and *σφαῖρα, sphere, or region.*)—That invisible elastic fluid which surrounds the Earth to an unknown height, and encloses it on all sides.

Atom, (*α, deprived of,* and *τεμνω, to divide.*)—An indivisible particle of matter.

Atomic Theory.—That doctrine of philosophy which explains the origin of all things by a combination of atoms. It was first taught by Mochus, of Sidon, who lived before the Trojan war: others are of opinion it was established by Leucippus, 510 B. C. Newton and Boerhaave supposed that the original matter consists of hard, ponderable, impenetrable, and inactive particles, the variety and composition of which causes the difference in bodies. A system founded on the theory of atoms is called *atomic,* and sometimes *corpuscular,* philosophy.

Attraction, (*attraho,* to draw to.)—That power or principle in matter by which all bodies mutually tend towards each other.

Attraction of Gravitation.—That force by which bodies descend towards the centre of the Earth.

Augmentation of Moon's Semi-diameter.—The increase due to the difference between her distance from the observer and the centre of the Earth.

August.—The eighth month of the year, called after the Emperor Augustus, who entered his second consulship in that month, after the Actian victory. Before that time it was called *Sextilis*. Our Saxon ancestors called it weod-monath, weed month.

Auriga.—One of the old northern constellations. R. A. 5*h*. 0*m*., Dec. 45° 0′ N.

Aurora.—The morning twilight.

Aurora Borealis, Aurora Septentrionalis, or **Northern Lights.**—A kind of meteor, appearing in the northern part of the heavens mostly in the winter season. It is generally believed to be an electrical phenomenon, although its origin is not certainly known.

Austral.—Southern. The six signs of the zodiac south of the equinoctial are called the Austral signs.

Autumn.—The third season of the year in the northern hemisphere, which commences at the descending equinox, when the Sun enters Libra.

Autumnal or **Descending Equinox.**—The time when the Sun enters Libra.

Axis, Conjugate.—That axis of an ellipse which bisects the transverse axis. It is the shorter of the two axes.

Axis, Declination.—The declination axis of a telescope is that axis of motion which is parallel to the plane of the equator.

Axis of a Lens.—An imaginary straight line, drawn from the centre of a spherical surface to the centre of that circle of which its surface forms an arc.

Axis, Major.—See Axis of an Orbit.

Axis, Minor.—See Axis of an Orbit.

Axis of an Orbit.—The line joining its perihelion and aphelion points; this is sometimes called the *major* axis. A line perpendicular to this, and passing through the centre of the ellipse, is called the *minor* axis.

Axis of a Planet, (*αξων, axis.*)—An imaginary line passing through its poles, upon which it revolves.

Axis, Polar.—That axis of motion of a telescope which is parallel to the axis of the Earth.

Axis of a Telescope.—An imaginary line passing through the centre of the tube.

Azelfafage.—Another name for the star π, in the constellation Cygnus.

Azha.—Another name for η Eridani, a star in the constellation Eridanus.

Azimuth.—The arc of the horizon contained between a vertical circle passing through the object, and the north or south points of the horizon. The word azimuth is pure Arabic, and signifies to move or go forward.

Azimuth Circles.—Great circles of the Sphere passing through the zenith and intersecting the horizon at right angles.

Azimuth Compass.—An instrument for finding either the magnetical azimuth or amplitude of a circle at sea. A compass used at sea for finding the horizontal distance of a celestial body from the magnetic meridian.

Azimuth, Magnetic.—An arc of the horizon contained between the magnetic meridian and the azimuth or vertical circle of the object.

Azimuthal Error, sometimes termed the **Meridian Error.**—The deviation of a transit instrument from the plane of the meridian. Its maximum is at the horizon, and at the zenith it is zero.

B.—In the astronomical tables B stands for Bissextile or Leap year.

Back Staff.—An instrument formerly used for taking the Sun's altitude at sea; so called because the back of the observer is turned towards the Sun during the observation. It was invented about the year 1590, by John Davis, a Welshman.

Baculometry, (*baculus*, a staff, and *μετρον*, a measure.)—The art of measuring altitudes by means of a staff.

Balance.—Another name for the sign Libra.

Barometer, (*βαρυς, heavy*, and *μέτρον, a measure.*)—An instrument invented by Torricelli for measuring the weight or pressure of the atmosphere; and, by means of the variations in the air, of foretelling changes in the weather. It is also used

for ascertaining the heights of mountains.

Base.—In geometry, the lowest side of the perimeter of a figure. Of a solid figure, the side on which it stands.

Base Line.—In surveying, a line measured with great exactness, on which a series of triangles is constructed in order to determine the distances and positions of objects. Astronomers make use of the Earth's diameter, and sometimes of the diameter of the Earth's orbit, for a *base line*.

Basilica or **Basiliskos.**—Another name for *Regulus*, which see.

Baten Kaitos.—Another name for ζ Ceti, a star in the constellation Cetus.

Bear, Great.—See URSA MAJOR.

Bear, Lesser.—See URSA MINOR.

Beard of a Comet.—The rays it emits in the direction in which it moves, as distinguished from the tail, or the rays emitted or left behind as it moves along.

Beid.—A name given to o Eridani, a star in the constellation Eridanus.

Bellatrix.—A bright star in the left shoulder of Orion. Its name is from the Latin *bellum*, as being supposed by the ancients to have an influence over warriors, and to kindle wars. It is also called γ Orionis.

Bellona.—The twenty-eighth asteroid. It was discovered by Luther, March 1, 1854.

Belts.—The dark bands which the telescope reveals on the bodies of the planets Jupiter and Saturn.

Benetnasch or **Alhaid.**—A bright star of the second magnitude in the extremity of the tail of Ursa Major, also called η Ursæ Majoris.

Bengalee Year.—This was once almost identical with the Hegira; but since the adoption of the solar computation it is now about nine years later than the Hegira. To bring the Bengalee year to the Christian era, the number 593 must be added.

Berenice's Hair.—See COMA BERENICES.

Betelgeux.—A fixed star of the first magnitude in the right shoulder of Orion, also termed α Orionis.

Biangular, (*bis*, twice, and *angulus*, an angle.)—Having two angles.

Bifid.—A term applied to the tails of comets which are separated into two branches.

Binary System.—A system of two stars revolving about a common centre of gravity.

Binocular Telescope, (*bini*, two together, and *oculus*, an eye.)—A telescope through which an object may be viewed by both eyes at the same time; now not used.

Binuclear.—A nebula having two nuclei is said to be *binuclear.*

Biquintile.—An aspect of the planets when they are 144° from each other.

Bisect, (*bis*, twice, and *seco*, to cut.)—To divide any thing into two equal parts.

Boreal Signs.—The first six signs of the zodiac, or those on the northern side of the equinoctial—viz., Aries, Taurus, Gemini, Cancer, Leo, and Virgo.

Bissextile or **Leap Year.**—A year consisting of 366 days. It occurs every fourth year, when a day is added to the month of February, which in that year consists of 29 days.

Bootes.—One of the old northern constellations, the middle of which is R. A. 14*h.* 28*m.*, Dec. 30° 0′ N.

Borealis.—Northern. See AURORA BOREALIS.

Botein.—Another name for ε Arietis, in the constellation Aries.

Brilliant Point.—That point from which the light of a surface is reflected to the eye in a direct line.

Brush.—A term applied to a comet's tail; and more especially when the tail is divided.

Bulk.—Volume; the relative bulk of two globes of unequal magnitude are to each other as the cubes of their diameters.

Bull's Eye.—By the Arabs called *Aldebaran*, which see.

Bungula.—A bright star in the constellation Centaurus, and marked α in the catalogues and maps.

Calbalacrab or **Kalb-al-akrab.**—Another name for Antares, a bright star in the constellation Scorpio.

Calendar.—Among the Romans the appearance of new moon was watched and public notice given of it. Hence the first day of every month was called *calends.*

It is now understood to be a distribution of time as accommodated to the uses of life; an almanac containing the order of the days, weeks, &c., in the year. See JULIAN YEAR and GREGORIAN YEAR.

Calippic Period.—A period of seventy-six years, invented by Calippus, an Athenian astronomer, as an improvement on the Metonic cycle of nineteen years. At every recurrence of this period he supposed that the mean new, and full moons would always return to the same day and hour.

Calliope.—The twenty-second asteroid. It was discovered by Hind, November 16, 1852.

Camelopardalus.—A northern constellation, the middle of which is R. A. 4*h.* 30*m.*, Dec. 70° 0′ N.

Cancer.—One of the twelve signs of the zodiac, the middle of which is R. A. 8*h.* 24*m.*, Dec. 20° 0′ N.

Canes Venatici.—A northern constellation in R. A. 13*h.* 12*m.*, Dec. 40° 0′ N. It is sometimes called *Asterion et Chara.*

Canicula.—A name given by the earlier astronomers to the constellations now called Canis Major and Canis Minor; also to Sirius, which is sometimes called the *dog star.*

Canicular Days, (*Dies Caniculares* or *Dog Days.*)—A certain number of days before and after the heliacal rising of *canicula*, or the dog star, in the morning.

Canicular Year.—The Egyptian natural year, which was computed from one heliacal rising of Sirius, or the dog star, to the next.

Canis Major.—A southern constellation. R. A. 6*h.* 20*m.*, Dec. 22° 0′ S.

Canis Minor.—A northern constellation. R. A. 7*h.* 22*m.*, Dec. 5° 30′ N.

Canopus.—A brilliant star of the first magnitude in the constellation Argo Navis, also known as *α* Argo Navis.

Capella.—A star of the first magnitude in the constellation Auriga, known as *α* Aurigæ. It was called by the Arabs *Hircus* or *Capra,* which means *the goat.*

Caph.—A star of the third magnitude in the constellation Cassiopeia, remarkable as being situated on the equinoctial colure. This star is also called *β* Cassiopeiæ.

Capra.—See CAPELLA.

Capricornus.—One of the signs of the zodiac, the middle of which is R. A. 20*h.* 40*m.*, Dec. 20° 0′ S.

Caput Medusæ.—A part of the constellation Perseus.

Cardinal Points of the Ecliptic.—The equinoctial and solstitial points—viz., Aries and Libra, Cancer and Capricorn.

Cardinal Points of the Heavens.—The zenith, the nadir, and the points where the Sun rises and sets.

Cardinal Points of the Horizon.—The east, west, north, and south points of the horizon.

Cardinal Signs.—Those signs at the equinoxes and solstices—viz., Aries, Libra, Cancer, and Capricorn.

Carina.—A name given to the *keel* of the ship in the constellation Argo.

Cassiopeia.—A northern constellation, the middle of which is R. A. 0*h.* 40*m.*, Dec. 60° 0′ N.

Castor.—A double star of the second magnitude in the constellation Gemini, also called *α* Geminorum.

Castor and Pollux. See GEMINI.

Catalogue.—A list of the principal fixed stars, in which may be found their right ascensions and declinations, as well as their latitudes and longitudes, with their variations, magnitudes, and proper motions.

Catoptrics.—That branch of optics which treats of the progress of rays of light after they are reflected from surfaces either plane or curved, and the formation of images from objects placed before such surfaces.

Cauda Leonis.—A fixed star of the first magnitude in the constellation Leo. See DENEBOLA.

Cela Sculptoria.—A small southern constellation. R. A. 4*h.* 44*m.*, Dec. 40° 0′ S.

Celæno.—A name given to one of the Pleiades.

Celestial Globe.—A representation of the heavens on an artificial globe, the principal stars being mapped out.

Celestial Latitude, Circle of.—A great cir-

cle of the sphere passing through the poles of the ecliptic, and consequently perpendicular to it.

Celestial Latitude, Parallels of.—Small circles of the celestial sphere parallel to the ecliptic.

Centaurus.—A southern constellation situated R. A. 13*h*. 30*m*., Dec. 50° 0′ S.

Centenary.—Belonging to a century, or a period of a hundred years.

Centesimal Division.—A division by hundreds. In astronomical tables the circumference of the circle is sometimes divided into 400 degrees, each degree into 100 minutes, and each minute into 100 seconds.

Central, (*centralis,* placed in the centre.)—Pertaining to the centre.

Central Eclipse.—This occurs when a line joining the centres of the Sun and Moon, and extended, would reach the eye of the spectator.

Central Forces.—Those forces which cause a moving body to tend towards or recede from the centre of motion; which are distinguished into two kinds—namely, *centrifugal* and *centripetal* force. See CENTRIFUGAL and CENTRIPETAL.

Central Latitude.—See LATITUDE.

Central Zenith.—See ZENITH.

Centre.—That point in a circle from which all lines drawn to the circumference are equal.

Centre of Gravity.—That point about which all the parts of a body do in any situation exactly balance each other.

Centre of Motion.—That point which remains at rest while all the points of a body move about it. The centre of motion of a ship is the point upon which, when in motion, the vessel oscillates or rolls.

Centrifugal, (*centrum,* a centre, and *fugio,* to fly from.)—That power which drives a revolving body from the centre.

Centripetal, (*centrum,* a centre, and *peto,* to seek.)—That power which attracts a revolving body to the centre of motion.

Century, (*centum,* a hundred.)—A hundred years.

Cepheus.—One of the northern constellations, the middle of which is R. A. 22*h*. 0*m*., Dec. 70° 0′ N.

Cerberus.—A northern constellation, the middle of which is R. A. 18*h*. 0*m*., Dec. 22° 0′ N.

Ceres.—The first asteroid. It was discovered by Piazzi, January 1, 1801.

Cetus.—A southern constellation, the middle of which is R. A. 1*h*. 40*m*., Dec. 12° S.

Chameleon.—A southern constellation. R. A. 11*h*. 0*m*., Dec. 78° S.

Characters.—Certain marks used by astronomers to denote the planets, signs of the zodiac, aspects, &c. ☉ *Sun;* ☿ *Mercury;* ♀ *Venus;* ⊕ *Earth;* ♂ *Mars;* ①②, &c., *the first, second, &c. asteroid;* ♃ *Jupiter;* ♄ *Saturn;* ♅ *Uranus;* ♆ *Neptune;* ♈ *Aries;* ♉ *Taurus;* ♊ *Gemini;* ♋ *Cancer;* ♌ *Leo;* ♍ *Virgo;* ♎ *Libra;* ♏ *Scorpio;* ♐ *Sagittarius;* ♑ *Capricornus;* ♒ *Aquarius;* ♓ *Pisces;* ☌ *Conjunction;* ☍ *Opposition;* △ *Trine;* □ *Quartile;* ⚹ *Sextile;* ● *New Moon;* ○ *Full Moon;* ☽ *Moon's first quarter;* ☾ *Moon's last quarter;* ☊ *Ascending node;* ☋ *Descending node;* ✱ *Star;* ⊕ *Globular cluster;* ○ *Planetary nebula;* ☾ *Moon above the horizon;* ☾☾ *Moon very bright;* I., II., III., IV., *Class one, two, three, four, of Sir W. Herschel's catalogue of nebulæ and clusters;* 10, 25, 38, &c., *number ten, twenty-five, thirty-eight, &c. of a class in the same catalogue.* Thus, II. 45 means class two, number forty-five, of Sir W. Herschel's catalogue. Δ signifies "Difference," or "North Polar Distance." Δ a means difference of right ascension, and Δ δ difference of declination. ✱ Δ signifies "Star's Polar Distance." ☄ is used to denote a comet. Thus, ☄ a or ☄ δ signifies the comet's right ascension or declination. ° degree, ′ minute, and ″ second, of angular measurement.

Cheleb.—Another name given to the star β Ophinchi, in the constellation Ophiuchus.

Chord, (χορδη, and the Latin word *chorda,* a string of a bow or musical instrument.)—A right line connecting the two extremes of an arc; so called from its resemblance to the chord or string of a bow.

Chronology, (χρονος, *time,* and λογος, *law* or *science.*)—The science which teaches the measure and division of time.

Chronometer, (*χρονος, time,* and *μετρον, a measure.*)—An instrument used for measuring time, as a clock, watch, &c. But the term is more particularly applied to a kind of clock so constructed as to measure minute divisions of a second.

Circe.—The thirty-fourth asteroid; discovered by Chacornac, April 6, 1855.

Circinus.—A small southern constellation. R. A. 15*h.* 0*m.*, Dec. 60° 0′ S.

Circle.—A plane figure bounded by a curved line called the circumference, which is everywhere equidistant from a point within it called the centre.

Circle, Almacantar, or **Circle of Altitude.**—A lesser circle of the sphere drawn parallel to the horizon.

Circles of Altitude.—Small circles parallel to the horizon, which serve to show the height of the Sun, Moon, or stars, above the horizon. See ALMACANTAR.

Circle of Celestial Longitude.—The ecliptic is called the circle of celestial longitude.

Circles, Concentric.—Those circles which have the same centre.

Circles of Declination.—Great circles of the sphere intersecting each other at the poles, and perpendicular to the equinoctial, on which declination is measured. This term denotes a small circle parallel to the equator.

Circle of the Disc.—That circle which divides the hemisphere of the Moon which is turned towards us from the hemisphere which is turned from us.

Circle, Great.—That which divides the sphere into two equal hemispheres, having the same centre and diameter with it.

Circle, Hour.—A small brazen circle fixed to the North Pole on the artificial globe, and divided into twenty-four parts or hours. It is furnished with an index, which points out the difference of meridians in time, and serves for the solution of many problems. In astronomy, the hour circle is a meridian of the Earth extended to the heavens, and passing through every 15° of the equinoctial.

Circle of Illumination.—That imaginary circle on the surface of the Earth which separates the illuminated from the darkened hemisphere.

Circle of Celestial Latitude.—See CELESTIAL LATITUDE.

Circle, Lesser.—A circle which divides a sphere into two unequal parts, having neither the same centre nor diameter with the sphere.

Circle of Perpetual Apparition.—A lesser circle parallel to the equator, and described by the most northern point of the horizon. All the stars included within this circle are continually above the horizon of any given place, and therefore never set.

Circle of Perpetual Occultation.—A small circle parallel to the equator, and described by the most southern point of the horizon. It contains all the stars which never appear or rise in the hemisphere of any given place.

Circles, Polar.—Two small circles parallel to the equator, at the distance of 23° 28′ from the poles. The northern is called the *Arctic*, the southern the *Antarctic*, circle.

Circle of Position.—A circle drawn through the intersections of the horizon and the meridian, and through a star, or any point of the sphere.

Circle, Primitive.—The great circle cut from the sphere by the plane on which the projection is made.

Circle of Right Ascension.—The same as the equator.

Circles of the Sphere.—Circles which cut or pass through the sphere and have their circumference upon its surface.

Circular Velocity.—The motion of a revolving body, measured by an arc of a circle.

Circumference, (*circum*, around, and *fero*, to carry.)—The line or lines which bound any figure; but more especially the curved line which bounds the circle, and is everywhere equidistant from a point within called the centre. If the diameter of the area be taken as 1, the circumference is equal in length to 3·1416, nearly.

Circumgyration.—The whirling motion of a body about a centre, as of the planets about the Sun.

Circumpolar Stars, (*circum*, round about.)

—Those stars which, owing to the latitude of the observer, revolve round the pole without setting.

Civil Day.—See DAY.

Civil Month.—See MONTH.

Civil Year.—The legal year, which every government appoints to be used within its own dominions.

Clamp.—A contrivance used for fixing certain parts of an instrument in an immovable position.

Clavius.—The name of a Lunar mountain.

Clepsydra, (*κλεπτω, to steal,* and *ὕδωρ, water.*) —A kind of water-clock, or an hour-glass, serving to measure time by the dropping of water from one vessel into another. By this instrument the Egyptians measured their time and the course of the Sun; and by it, in modern times, Tycho Brahê measured the motions of the stars.

Clio.—The twelfth asteroid; discovered by Hind, September 13, 1850.

Clock.—A machine so regulated by the uniform motion of a pendulum as to measure time with accuracy. The invention of the clock is ascribed to Pacificus, archdeacon of Verona, in the ninth century; others attribute the invention to Boethius, about the year 510. A common clock indicates mean solar time, but clocks used in observatories show sidereal time.

Clock Stars.—Stars which serve to regulate astronomical clocks, their situations or places having been very exactly determined.

Cluster.—A collection of stars very closely congregated. Those assemblages which require the aid of very powerful telescopes to resolve or separate them, are generally termed clusters.

Coal-Sack.—A small portion of the heavens in the southern hemisphere, near the Southern Cross, which, to the naked eye, appears entirely devoid of stars; but when the telescope is applied, extremely small stars are perceptible throughout. It has received the name of coal-sack because it appears perfectly black when contrasted with the adjacent bright portions of the Milky Way.

Coincide.—Two surfaces are said to coincide when their forms agree with each other throughout.

Co-Latitude.—The complement of the latitude, or its difference from 90°.

Collimation, (*con,* with, and *limes,* a limit.) —The line in a telescope which passes through the intersection of the cross-wires fixed at the common focus of the lenses. The line drawn through the optical centres of the eye and the object-lenses.

Collimation, Error of.—A deviation of the centre wire of a transit instrument from its optical axis.—*Hind.*

Collimator.—An instrument for ascertaining the horizontal point, or correcting the error of collimation in an instrument.

Columba.—A southern constellation. Its R. A. is 5*h.* 40*m.*, Dec. 35° 0′ S.

Colures, (*κολος, mutilated,* and *ουρα, a tail;* so called because a portion of it is always below the horizon.)—Two great imaginary circles intersecting each other at right angles at the poles; the one passing through the equinoctial, and the other through the solstitial, points.

Colure, Equinoctial.—That colure which passes through the equinoctial points Aries and Libra.

Colure, Solstitial.—That colure which passes through the solstitial points Cancer and Capricorn.

Coma, (derived from a Greek word signifying hair.)—A dense, nebulous covering of a comet, called also the *Envelope,* which sometimes renders the nucleus indistinct. The *Tail* is regarded as an expansion or elongation of the coma.—*Olmsted.*

Coma Berenices.—One of the northern constellations, the middle of which is R. A. 12*h.* 30*m.*, Dec. 27° 0′ N.

Comes.—An attendant or companion star. When two stars appear very near each other, the less bright of the two is called the *comes.*

Comet, (*κομάω, hairy.*)—This name is given to bodies belonging to our system with highly eccentric orbits, and whose motion is not always in the order of the signs, but sometimes direct, and at others retrograde. They are not confined to any portion of the heavens, but may be

seen in all directions. By some early writers they were called *shode stars.*

Cometary Astronomy.—The astronomy of comets, embracing all their appearances and motions.

Cometarium.—A machine representing the motion of a comet round the Sun.

Comet-Finder.—A telescope having a large object-glass, of large aperture and short focal length.

Cometography.—A history and description of comets.

Commeasurable Distance.—A distance which can be measured instrumentally, or by calculation.

Communication of Motion.—That act of a moving body by which it gives motion, or transfers its motion, to another body.

Commutation, Angle of.—The distance between the Sun's true place, as seen from the Earth, and the place of a planet reduced to the ecliptic.

Compass.—A general name given to those instruments used to determine the direction of the magnetic meridian, and also to designate the angular distance between that meridian and any horizontal line.

Compass, Azimuth.—An instrument used for taking the bearing of any celestial object when it is in or above the horizon, that from the magnetic azimuth or amplitude the variation of the needle may be known. This compass differs from the mariner's compass in having the circumference of the card or box divided into degrees and quarter degrees. Attached to the box is an index with two sights, through which the Sun or a star is to be viewed at the time of observation.

Compass, Mariner's.—An instrument used at sea to direct and ascertain the course of the vessel. It consists of a circular brass box, containing a paper card on which is marked the thirty-two points of the compass. This card is fixed on a magnetic needle, so that the point of the card marked north is always directed towards that point of the heavens. The invention of the compass is usually ascribed to Flavio Givia, about the year 1302; it was then divided into eight points. By some the invention is ascribed to the Chinese, for their emperor, Chiningus, is said to have had a knowledge of it 1120 B.C. The Chinese compass was then divided into twenty-four parts. See *Hutton's Mathematical Dict., art. Compass.*

Compass, Variation.—A compass of very delicate construction, intended to indicate the daily variation of the magnetic needle.

Compass, Variation of.—The deviation of its points from the corresponding points in the heavens. When the needle points to the east of the true north point of the heavens, the variation is east; if it be to the west, the variation is west.

Complement.—That which is wanting to complete some certain quantity.

Complement of an Arc or Angle.—That which any given arc or angle wants of 90°. Thus, the complement of 50° is 40°.

Composition of Forces, or Motion.—The union or assemblage of several forces or motions that are oblique to one another, into an equivalent one in another direction.

Compound Motion.—That motion which is the effect of several conspiring powers or forces.

Compression of the Poles.—The amount by which the polar is shorter than the equatorial diameter, owing to the flattening of a planet at its poles.

Concave.—The inner surface of hollow bodies, more especially of spherical or circular ones.

Concave Lens.—See LENS.

Concentric, (*con,* with, and *centrum,* a centre.)—Having the same centre.

Cone.—A round pyramid or solid body, having a circle for its base, and its sides formed by right lines drawn from the circumference of the base to a point at the top, being the vertex or apex of the cone. A right line drawn from the vertex to the centre of the base is termed the *axis* of the cone.

Cone of Rays.—The rays of light which fall from a luminous point upon a given surface, as upon the object-glass of a telescope.

Conic Sections.—That science which treats

of the curved lines and plane figures which are produced by the intersection of a plane with a cone.

Conjugate Axis.—See AXIS.

Conjugate Diameter.—The same as conjugate axis. See AXIS.

Conjunction.—The meeting of two heavenly bodies in the same point or place in the heavens.

Conjunction, Apparent.—The situation of two bodies being such that a line drawn through their centres and produced, passes through the eye of the observer, but not through the centre of the Earth.

Conjunction, Inferior.—When a planet is in inferior conjunction, its geocentric longitude is the same as that of the Sun; but the difference between the geocentric and heliocentric longitudes equals 180°.

Conjunction, Superior.—The interior planets, Mercury and Venus, are in superior conjunction when they have the same geocentric longitude as the Sun, but are beyond that luminary as seen from the Earth.

Conjunction, True.—The situation of two bodies being such that a line drawn through their centres and produced, will pass through the centre of the Earth and the eye of the observer.

Consequentia.—In the order of the signs.

Constant of Aberration.—Light is 8*m.* 17·8*s.* in travelling from the Sun to the Earth. In this interval the Earth has moved, with her average velocity, through an arc of 20·45″, which is, therefore, the amount of displacement in the Sun's longitude, arising from the progressive motion of light, and is termed the *constant of aberration.*—*Hind.*

Constant Quantities.—Quantities which remain invariably the same, while others increase or decrease.

Constellation, (*con*, with or together, and *stella*, a star).—A group or collection of stars. The constellations are represented on maps and globes by figures of animals, &c. The constellations are divided into northern and southern. The northern are those north of the zodiac; the southern, those south of it.

Constellations, Northern.—Those constellations north of the zodiac.

Constellations, Southern.—Those constellations south of the zodiac.

Constellations, Zodiacal.—Those twelve constellations situated in the zodiac.

Contact, (*contingo*, to touch.)—The relative state of two bodies which touch each other without cutting or entering; the parts touching each other are called the *points of contact.*

Contact, Angle of.—The angle made by a curved line and a tangent to it.

Contact, External.—The *first* external contact is when the disc of a planet apparently first touches the disc of the Sun; the *last* external contact is when the planet has passed over the Sun, and their discs are just about being separated.

Contact, Internal.—The *first* internal contact is when the disc of the planet is apparently just perfectly on the Sun's disc; and the last internal contact is when the planet has passed over the Sun's disc, but its edge has not yet projected beyond the Sun's limb.

Converge, (*con*, with, and *vergo*, to incline.) —To tend or incline towards the same point. When two straight lines converge, they will meet if produced sufficiently.

Converging Rays.—Those rays which tend to a common focus.

Convex, (*convexus*, arched.)—Curved and protuberant outwards, as the surface of a globe or sphere.

Copernican System.—The solar system as it is now understood—that is, the Sun in the centre, and the Earth, planets, and comets revolving around him. It is so called from its founder, Nicholas Copernicus, who was born A. D. 1473, at Thorn, in Prussia. This system was first proposed by Pythagoras, and revived by Copernicus.

Copernicus.—The name of a lunar mountain.

Cor Caroli.—One of the northern constellations, situated R. A. 12*h.* 48*m.*, Dec. 40° 0′ N.

Cor Hydra.—The chief star in the constellation Hydra, also known as *α* Hydræ, or *Alphard.*

Cor Leonis.—See Regulus.

Cor Scorpii.—See Antares.

Corona.—The circle of light often seen in total eclipses of the Sun. It is believed by some to be the atmosphere of the Sun rendered visible by the intervention of the Moon.

Corona Australis.—A southern constellation. R. A. 18*h.* 40*m.*, Dec. 40° 0′ S.

Corona Borealis.—A northern constellation, the middle of which is R. A. 15*h.* 25*m.*, Dec. 28° N.

Corpuscular Theory, (*corpusculum,* a small body.)—A theory which teaches that all luminous bodies emit, with extreme velocity, infinitely small particles, or *corpuscles;* which are, in fact, portions of solid matter, which we call light.

Corvus.—A southern constellation. R. A. 12*h.* 21*m.*, Dec. 20° 0′ S.

Co-sine.—The sine of the complement of an angle.

Cosmical Rising or Setting, (*κοσμος, the world,* the universe.)—A star rises or sets cosmically when it rises or sets when the Sun rises.

Cosmogony.—The science of the formation of the universe.

Cosmolabe, (*κοσμος, world,* and *λαμβανω, to take.*)—An instrument formerly used for measuring angular distances between the heavenly bodies. It was also called a *pantocosm,* from *παν, all,* and *κοσμος, world.*

Cosmology, (*κοσμος, world,* and *λογος, discourse.*)—The science which treats of the general laws by which the physical world or universe is governed.

Cosmometry, (*κοσμος, world,* and *μετρον, a measure.*)—The art of measuring in degrees, the world or sphere.

Co-tangent.—The tangent of an arc which is the complement of another to 90°, or what the arc wants of a quadrant.

Cotidal Lines.—Those lines on the Earth's surface connecting those places at which it is high or low water, or any other corresponding phases of the tides.

Course.—The direction in which motion is performed.

Co-versed Sine.—The versed sine of the complement of an arc or angle.

Crater.—A southern constellation, situated R. A. 11*h.* 8*m.*, Dec. 15° 0′ S.

Crepusculum or Twilight.—The time from the first dawn of morning to the rising of the Sun; and again, between the setting of the Sun and the last remains of day. The boundary line of twilight is about 18° from the horizon.

Crescent, (*cresco,* to grow.)—This term is applied to the new moon, which, as it recedes from the Sun, shows a small rim of light, which increases till it is full. When less than one-half of the illuminated disc of a heavenly body is visible, it is said to present the form of a crescent.

Crinus.—A name applied to the faint luminosity surrounding the head of a comet, now generally called the *coma.*

Crux.—A splendid southern constellation, situated R. A. 12*h.* 20*m.*, Dec. 60° S.

Crystalline Spheres.—Two spheres, supposed by the ancient astronomers to be placed between the *Primum Mobile* and the firmament, and by which they explained the motions of the stars, &c.

Culminating Point.—That point of the circle of a sphere which is on the meridian.

Culmination, (*culmen,* the highest point.)—The passage of a star or planet over the meridian.

Culmination, Lower.—The passage of a circumpolar star across the meridian *below* the pole.

Culmination, Upper.—The passage of a circumpolar star across the meridian *above* the pole.

Cursa.—A name given to the star in the constellation Eridanus, called also β Eridani.

Curtate Distance, (*curtatus,* shortened.)—The distance of the place of a body from the Sun, reduced to the ecliptic; or the interval between the Sun and that point where a perpendicular let fall from the body meets the ecliptic.

Curve, (*curvus,* bent.)—A line whose direction is always changing, in distinction from a straight line whose direction is always the same at every point.

Curvilinear.—Relating to curves. Those figures formed or bounded by a curved line or lines.

Cusp, (*cuspis*, a point.)—The points or horns of the Moon or other luminary which assumes the crescent form.

Cycle, (*κυκλος, a circle.*)—A certain period of time in which the same phenomena return; a periodical space of time.

Cycle, Calippic.—A cycle of 76 years, or four Metonic cycles. This cycle, a great improvement on that of Meton, was first proposed by Calippus.

Cycle of Eclipses.—A period of about 6586 days, which being the time of a revolution of the Moon's node, the eclipses return in nearly the same order again. This cycle was called by the ancient Chaldeans *Saros*.

Cycle of Indiction.—See INDICTION.

Cycle, Lunar.—A period of 19 years, in which time the new and full moons return to the same day of the year, but not to the same hour of the day. This is also called the Metonic cycle.

Cycle, Solar.—A period or revolution of 28 years, at the end of which time the days of the month return again to the same days of the week. The same order of Leap years and of the Dominical letters returns to the same days of the week; hence it is also called the *cycle of the Sunday letter*.

Cyclometry, (*κυκλος, a circle*, and *μετρεω, to measure.*)—The art of measuring circles.

Cygnus.—A beautiful northern constellation. R. A. 20*h.* 26*m.*, Dec. 42° N.

Cynosura.—A name given by the Greeks to Ursa Minor or Little Bear, the star in the extremity of the tail being called the Pole Star, North Star, or Cynosura.

Dabih.—A star in the constellation Capricornus, also known as β Capricorni.

Daily.—Diurnal.

Day.—A division of time caused by the appearance and disappearance of the Sun.

Day, Artificial.—The interval of time which elapses from the rising to the setting of the Sun, or the time when the Sun is above the sensible horizon.

Day, Astronomical or **Solar.**—The term of twenty-four hours, beginning when the Sun's centre is on the meridian of any place, and ending when his centre arrives at the same meridian again. Thus, 9 o'clock in the morning of February 14, is called by astronomers February 13, twenty-one hours.

Day, Civil.—The time allotted for day, which includes one whole rotation of the Earth on its axis; but which begins differently in different nations. In the United States, and in Europe generally, the civil day begins at midnight, and continues twenty-four hours.

Day, Mean Solar.—The period of twenty-four hours measured by equal motion, as that of a clock.

Day, Sidereal.—The sidereal day is the time which elapses between two consecutive transits of any star at the same meridian. This measure of time is invariable, not being, as the solar day, affected by the yearly revolution of the Earth. The sidereal day is 3*m.* 55·91*s.* less than the mean solar day.

December, (*decem*, ten.)—In the Roman year this was the tenth month, but is the twelfth according to our reckoning. In this month the Sun enters Capricorn, which is the winter solstice. It was a season of festivity among the ancients.

Dechotomy.—See DICHOTOMY.

Decil.—An aspect or position of two planets when they are distant from each other 36°, or a tenth part of the zodiac.

Decimal System, (*decem*, ten.)—That system of calculation in which numbers are expressed by tens.

Declination, (*declino*, to slope.)—The distance of a heavenly body from the equinoctial, either north or south.

Declination Axis.—That axis of an equatorial telescope which is parallel to the plane of the equator.

Declination, Circles of.—Great circles passing through the poles, on which declination is measured. They are the same as meridians in geography.

Declination of the Compass.—Its deviation from the true meridian. See VARIATION.

Declination (Instrumental) of an Object.—The angular distance of an object from a plane perpendicular to the polar axis, and estimated upon the declination circle.

Declination, Parallax of.—An arc of the circle of declination, by which the parallax in altitude increases or diminishes the declination of a star.

Declination, Parallels of.—Lesser circles parallel to the equinoctial. The Tropic of Cancer is a parallel of declination 23° 28′ north, and the Tropic of Capricorn is a parallel of declination the same distance south of the equinoctial.

Declination, Refraction of.—An arc of the circle of declination, by which the declination of a star is increased or diminished by means of the refraction.

Deferent.—See EXCENTRIC CIRCLE.

Degree.—The 360th part of a great circle. Every degree (marked °) is divided into 60 minutes, (marked ′,) each minute into 60 seconds, (marked ″,) each second into thirds, (‴,) fourths, (⁗,) &c.—each term being a 60th part of its predecessor.

Degree of Latitude.—The space or distance on the meridian through which an observer must move to vary his latitude by one degree, or to increase or diminish the distance of a star from the zenith by one degree.

Degree of Longitude.—The space between two meridians that make an angle of one degree with each other at the poles, the quantity of which is variable according to the latitude, being everywhere as the co-sine of the latitude.

Delphinus.—One of the northern constellations, the middle of which is situated R. A. 20*h*. 32*m*., Dec. 12° 0′ N.

Deneb.—Another name for α Cygni, a star in the constellation Cygnus. It is also called Arided.

Deneb Algedi.—A name given to a star in the tail of Capricornus, also called γ Capricorni.

Deneb Kaitos.—See DIPHDA.

Denebola.—A bright star in the constellation Leo, also called β Leonis. This star sometimes receives the appellation of *Serpha.*

Dense Matter.—Matter whose particles are compressed together with a certain degree of closeness.

Density, (*densitas,* closeness.)—That property of bodies by which they contain a certain quantity of matter within a certain bulk or magnitude.

Depression of the Horizon.—See DIP OF THE HORIZON.

Depression of the Pole.—The appearance of a receding of the pole when the observer travels towards the equator, owing to the spherical figure of the Earth.

Depression of the Sun or a Star.—Its distance below the horizon; it is measured by an arc of a vertical circle intercepted between the horizon and the place of a star.

Descending Constellations.—Those constellations through which the planets descend towards the south, as Cancer, Leo, Virgo, &c.

Descending Node.—That point in a planet's orbit where it intersects the ecliptic proceeding southward. It is marked thus ☋.

Descending Signs.—Those signs of the zodiac from the Tropic of Cancer to that of Capricorn are called the *descending* signs.

Descension, Oblique.—A point or arc of the equator which descends at the same time with a star or sign below the horizon in an oblique sphere.

Descension, Right.—A point or arc of the equator which descends with a star or sign below the horizon in a right sphere.

Dheneb el'Okab.—A star in the constellation Aquila, known as ζ Aquilæ.

Diagonal, (*δια, through,* and *γωνια, a corner.*)—A right line drawn across a figure from one angle to another; it is sometimes called a diameter.

Diagram.—A drawing or pictorial delineation, made for the purpose of demonstrating or illustrating some description.

Dial, (*dies,* a day.)—An instrument serving to measure time by the shadow of the Sun. The ancients called it *sciathericum,* because it indicated the hour of the day by the shadow.

Diameter of a Circle, (*δια, through,* and *μετρον,* a *measure.*)—A right line passing through the centre of a circle, and terminated at the circumference on both sides.

Diameter, Apparent.—The angle the true

diameter of a heavenly body subtends to the eye of the observer.

Diameter, Conjugate.—That diameter of an ellipse which bisects the transverse axis. It is the same as the conjugate axis.

Diameter, Equatorial.—A line passing through the centre of a sphere and terminated at the equator; that is, at an equal distance from each pole.

Diameter, Polar.—The line passing through the centre of a sphere and terminated by the poles.

Diameter, Transverse.—The longer of the two unequal diameters of an ellipse. It is also called the *greater* or *transverse axis.*

Diameter, True or **Real.**—The distance measured by a line passing through the centre of a heavenly body and terminating at its surface.

Diaphanous.—Translucent. A body or medium through which the rays of light may easily pass, as water, air, glass, talc, fine porcelain, &c.

Diaphram.—A species of micrometer.

Dichotomy.—A term denoting an aspect of the Moon when she is in quadrature, or shows only one-half of the hemisphere which is turned towards the Earth. In this situation she is said to be *dichotomized* or *dichotomous.*

Differentiate.—To fix the position of a celestial object by comparing it with another.

Digit, (*digitus,* a finger.)—A measure by which eclipses are estimated, being the twelfth part of the diameter of a luminary. It is an ancient measure, of a finger's breadth. If the Sun or Moon are said to be six digits eclipsed, it means that *half* the disc is invisible.

Dione.—The fourth satellite of Saturn. It was discovered by Dominic Cassini, in March, 1684.

Diopter or **Dioptra.**—An instrument invented by Hipparchus, which served to level water-courses, to ascertain the height of towers, to determine the magnitudes, distances, &c. of the planets.

Dioptrics.—That part of optics which treats of the effects of light as refracted by passing through different media, as air, water, glass, and especially the different kinds of lenses.

Dip of the Horizon.—The vertical angle contained between a horizontal plane passing through the eye of the observer, and a line from his eye to the unobstructed sensible horizon.

Diphda.—A star of the third magnitude in the constellation Cetus, also known as β Ceti. This star is sometimes called *Deneb Kaitos,* and by the Arabs was named *Rana Secunda.*

Direct Motion.—See Motion.

Disc, (*δισκος, a dish or quoit.*)—The body or face of the Sun, Moon, or planets.

Disc, Circle of.—See Circle of the Disc.

Distance.—The space separating the centres of two stars, expressed in seconds of arc.

Diurnal.—Relating to the day.

Diurnal Aberration.—See Aberration.

Diurnal Arc.—The arc described by the Sun, Moon, or stars, between their rising and setting.

Diurnal Circle.—The apparent circle described by the celestial bodies in consequence of the rotation of the Earth.

Diurnal Motion.—See Motion.

Diurnal Motion of the Earth.—The rotation of the Earth round its axis, the duration of which constitutes the natural day.

Diurnal Motion of a Planet.—The number of degrees, minutes, &c. which any planet moves in twenty-four hours.

Diurnal Parallax.—See Parallax.

Diurnal Revolution.—The revolution which any celestial body performs on its own axis.

Diverging.—Receding, separating.

Dodecatemorion.—The twelve signs of the zodiac; also the twelfth part of every sign.

Dog.—A name common to two constellations—the Great and Little Dog; but more usually known by the name of Canis Major and Canis Minor.

Dog Days.—See Canicular Days.

Dog Star.—The same as Sirius, which see.

Dominical Letters.—One of the first seven letters of the alphabet, otherwise called

the Sunday letter. They are used in almanacs to denote the Sundays throughout the year.

Doppelmager.—A spot on the lunar surface, to which this name is given.

Dorado or **Xiphias.**—A southern constellation, situated in R. A. 5*h.* 0*m.*, Dec. 62° 0′ S.

Double Nebulæ.—See NEBULÆ.

Double Stars.—Two stars connected in one system, having a motion round the same centre. Double stars can only be distinguished by means of a telescope.

Double Stars, Conspicuous.—Those double stars in which both individuals exceed the 8·25 magnitude.

Double Stars, Optical.—Two stars, one of which is nearly on a line with the other more distant star and the observer's eye, but which have no revolution round a common centre of gravity, and are not members of the same system.

Double Stars, Physical.—Two stars which revolve round the same centre of gravity, and which form a binary system.

Double Stars, Residuary.—Those double stars in which both individuals are below the 8·25 magnitude.

Draco.—A northern constellation. R. A. 18*h.* 0*m.*, Dec. 65° N.

Dubhe.—A star in the constellation Ursa Major, termed α Ursa Majoris. It is noted as constituting one of the *Pointers.*

Dynameter.—An instrument used for obtaining the measure of the magnifying power of telescopes. It was invented by Ramsden.

Dynamical Law.—The law which governs the motions of moving bodies, or of matter.

Dynamics.—The science of moving powers, or of matter in motion: the motion of bodies that mutually act on each other.

Earth.—The third planet from the Sun; the globe on which we live: marked by the astronomical character ⊕.

Earth-light.—The faint light which is seen on the Moon at the time of new moon, and is the sunlight reflected from the Earth.

East.—One of the cardinal points of the horizon or of the compass, being the middle point between north and south.

Ebb Tide.—The receding of the sea after high tide. See TIDES.

Eccentric.—Those figures, circles, spheres, &c. which have not the same centre The term is opposed to concentric, which signifies having the same centre.

Eccentric Anomaly.—See ANOMALY.

Eccentric Place in the Ecliptic.—A point of the ecliptic to which a planet, as seen from the Sun, is referred; or, the place of a planet reduced to the ecliptic. See HELIOCENTRIC LONGITUDE.

Eccentricity.—The distance between the Sun and the centre of a planet's orbit.

Eclipse, (εκλειπω, *to disappear.*)—A privation of the light of a luminary by the interposition of some opaque body either between it and the eye, or between it and the Sun.

Eclipse, Annular.—The total obscuration of the Sun, except a luminous ring round its edge.

Eclipse, Central.—An eclipse in which the centres of the two luminaries and the Earth come into the same straight line.

Eclipse of the Moon.—The privation of the light of the Moon, occasioned by the interposition of the Earth.

Eclipse, Partial.—An eclipse in which only a portion of the luminary is obscured.

Eclipse of the Sun.—An occultation of the Sun's body, caused by the interposition of the Moon between the Sun and the Earth.

Eclipse, Total.—An eclipse in which the whole luminary is darkened.

Ecliptic, (ἐκλειπτικὸν, so called because the eclipses of the Sun and Moon always happen under it.)—A great circle of the sphere, conceived to pass through the middle of the zodiac; it is the apparent path of the Sun, or the real path of the Earth.

Ecliptic Conjunction.—The conjunction of the Sun and Moon at the time of new moon, both luminaries having then the same longitude.

Ecliptic Limit, Lunar.—If the Moon be within 12° of her node at the time of full, she will be more or less eclipsed. This space of 12° is called the *lunar ecliptic limit.*

Ecliptic Limit, Solar.—If the Moon be within 17° of her node at the time of new moon, she will eclipse the Sun; hence this space of 17° is called the *solar ecliptic limit.*

Ecliptic, Obliquity of.—The angle or inclination of the Earth's equator to the plane of her orbit.

Egeria.—The thirteenth asteroid, discovered by De Gasparis, November 2, 1850.

Egress.—The passing off of an inferior planet after a transit over the Sun's disc.

Egyptian System.—That system of the universe as taught by the Egyptians.

Electra.—A name given to one of the Pleiades.

Elements.—Those principles deduced from astronomical observations and calculations, and those fundamental numbers which are employed in the construction of tables of the planetary motions. The elements of a planet's orbit are seven in number.

Elements of an Orbit.—These are the mean distance, eccentricity, longitude of the perihelion, periodic time, longitude of the ascending node, inclination of the orbit, and longitude of the epoch.

Elevation of the Equator.—The height of the equator above the horizon. The elevation of the equator and of the pole taken together equals 90°. The elevation of the pole being found and subtracted from 90° leaves the elevation of the equator.

Elevation of the Pole.—The angle or arc of the meridian intercepted between the horizon and the pole. It is always equal to the latitude of the place.

Elevation of a Star.—Its angular height above the horizon; or an arc of the vertical circle intercepted between the star and the horizon.

Ellipse.—One of the conic sections, popularly called an *oval.* It was first called an ellipse or ellipsis by Appolonius, the first and principal author of the conic sections.

Ellipticity.—Eccentricity, or deviation from the circular or spherical form. In the terrestrial spheroid, it is the ratio or difference between the two semi-axes.

El Nath.—A bright star in the constellation Taurus, known also as β Tauri.

Elongation.—The angular distance of a planet east or west of the Sun. This term is generally applied to the interior planets.

Elongation, Angle of.—An angle contained under lines supposed to be drawn from the centres of the Sun and a planet to the centre of the Earth.

El Rischa.—The Arabic name for the star known as α Piscium, in the constellation Pisces. It was also called Okdah. The Greeks called this star Syndesmos.

Embolimæus.—Intercalary; a term used for that of Bissextile or Leap year.

Emersion.—The reappearance of the Sun, Moon, planet, or star, after having suffered an eclipse.

Enceladus.—The second satellite of Saturn; it was discovered by Sir W. Herschel, August 19, 1787.

Engonasis.—The same as Hercules. See Hercules.

Enif.—Another name for ε Pegasi, a star in the constellation Pegasus. This star is sometimes called Enir.

Envelope.—A term applied to that nebulous covering of the head of a comet also known by the name of *coma.*

Epact.—The excess of the solar month above the lunar synodical month; or of the solar year above the lunar year of twelve synodical months.

Ephemeris, (ἡμέρα, *a day.*)—Tables calculated by astronomers, showing the state of the heavens for every day at noon; that is, the places of all the planets, &c. for each day.

Epicycle.—In the Ptolemaic astronomy, a small circle whose centre is in the circumference of a greater, which, being fixed in the deferent of a planet, is carried along with it, and yet with its own peculiar motion carries the body of the planet attached to it round its proper centre.—*Ptol. Almag.* l. iii. c. 3.

Epoch.—A fixed point of time, from whence succeeding years are numbered or reckoned. Different nations have different epochs. The Christians chiefly use the Epoch of the Nativity of Christ; the Mo-

hammedans, the Hegira; the Jews, the Creation of the World, or the Deluge; the ancient Greeks, the Olympiads; the Romans, the building of their city, &c. Also, the time to which certain given numbers or quantities apply.

Epoch of the Mean Longitude.—The mean longitude of a planet computed for a fixed date. This is also called the *longitude of the epoch.*

Equable Motion.—See MOTION.

Equation of the Centre.—The difference between the true and mean place of a planet. It is also called *Prosthapheresis.*

Equation of Equinoxes.—The difference between the mean and apparent places of the equinox.

Equation of the Equinoxes in Right Ascension.—The distance from the reduced place of the mean equinox to the apparent equinox.

Equation, Personal.—A personal equation is the difference of time with which two observers note the transit of a star over each of the wires of an instrument.

Equation of Time.—The difference between mean and apparent time, or the difference between the Sun's mean motion and his right ascension.

Equation of Sidereal Time.—The difference between apparent and mean sidereal time.

Equator.—A great circle of the Earth, equally distant from its two poles. It is sometimes, by seamen, called the *Line.*

Equatorial Diameter.—The diameter of a sphere measured through the centre and terminated both ways by points on the surface situated at equal distances from both poles.

Equatorial Horizontal Parallax.—See PARALLAX.

Equatorial Telescope.—A telescope so adjusted as to have two axes of motion at right angles to each other, one axis being parallel to the axis of the Earth, the other parallel to the plane of the equator. The motion which is parallel to the plane of the equator being perfectly uniform, when a star is kept constantly in the field of view, can be performed by means of clock-work attached to the instrument.

Equi-angular.—Having equal angles.

Equilateral, (*æquabilis,* of the same dimensions, and *latera,* side.)—Having equal sides. Triangles which have all their sides equal are said to be equilateral.

Equilibrium, (*æquus,* equal, and *libra,* a balance.)—An equality between two forces acting in opposite directions; an equality of weight.

Equinoctial.—A great circle in the heavens under which the equator moves in its diurnal motion: the plane of the equator extended to the heavens.

Equinoctial Colure.—A great circle passing through the poles of the heavens and the equinoctial points.

Equinoctial Points.—Those points where the equator and ecliptic intersect each other.

Equinoctial Time.—See TIME.

Equinoxes, (*æquus,* equal, and *nox,* night; because then the days and nights are equal.)—The time when the Sun enters the equinoctial points. *Vernal equinox* is about the 21st of March; the *autumnal equinox* about the 22d of September.

Equuleus.—A northern constellation, the middle of which is R. A. 21*h.* 4*m.*, Dec. 5° 0′ N.

Equuleus Pictorius.—A southern constellation, the middle of which is R. A. 5*h.* 30*m.*, Dec. 52° 0′ S.

Era.—A fixed point of time; an epoch. Also, a way or mode of counting time.

Era, Christian.—The computation of time from the birth of Christ, which was not introduced till the sixth century, in the reign of Justinian. Before that period time was computed from the Olympiads, the year of Rome, &c.

Era of Nabonassar.—An epoch of time reckoned from B. C. 747; it is of importance in astronomical chronology.

Eratosthenes.—The name of a lunar mountain.

Eridanus.—A southern constellation, the middle of which is R. A. 4*h.* 0*m.*, Dec. 10° S.

Errai.—A star in the constellation Cepheus, known as γ Cephei.

Erratic.—A term applied to the planets, which are called erratic or wandering stars.

Error of the Clock.—The error of the clock is its difference from true sidereal time.

Establishment of the Port.—The difference between the actual and theoretical time of high water at any place.

Etamin.—A star situated in the constellation Draco, also known as γ Draconis.

Eunomia.—The fifteenth asteroid; it was discovered by Gasparis, July 29, 1851.

Euphrosyne.—The thirty-first asteroid; it was discovered by Ferguson, September 1, 1854.

Euterpe.—The twenty-seventh asteroid; it was discovered by Hind, Nov. 8, 1853.

Evection.—The Libration of the Moon; an inequality in her motion, caused by a change in the eccentricity of her orbit, whereby her mean longitude is sometimes increased or diminished to the amount of 1° 20′.

Excentric Circle.—In the ancient Ptolemaic astronomy, was the orbit which the planet was supposed to describe about the Earth, and which was supposed to be eccentric with it. It was also called the *deferent.*

Excentricity.—The deviation of an elliptical orbit from a circle. It is usually expressed in parts of the mean distance of a planet or comet. See Angle of Eccentricity.

Excursion.—Another word for elongation.

Exterior Angle.—See Angle.

Exterior Planets.—Those planets whose orbits are beyond the orbit of the Earth.

Eye-piece, Diagonal.—A flat piece of polished metal placed between the two lenses of the eye-piece at an angle of 45°; a rectangular prism of glass is often used instead of the metal.

Eye-piece, Negative.—The negative eyepiece is formed of two plano-convex lenses placed with their curved faces towards the object-glass.

Eye-piece, Positive.—The positive eyepiece is formed of two plano-convex lenses, having their curved faces turned towards each other.

Eye-piece of a telescope.—A microscope, composed of two or more lenses, applied to the eye-end of the telescope.

Face.—The plane surface of any solid.

Faculæ, (*facula,* a small torch.)—Spots on the Sun, more luminous than the other parts of his surface.

Falcated, (*falx,* a sickle, or reaping-hook.)—One of the phases of the Moon or planets, otherwise called horned. When the enlightened part appears in the form of a crescent or sickle, it is said to be falcated.

Falling Stars.—See Meteor.

Fasciæ.—See Belts.

February, (so called from *Februa,* a Roman feast held in that month.)—The second month of the year, containing 28 days for three years, and every fourth year 29 days. In the first ages of Rome February was the last month in the year, and preceded January till the Decemviri made an order to place it after January. See Bissextile.

Field of View.—That portion of the heavens visible at one time through a telescope. The fields of telescopes differ according to their powers.

Figure.—In geometry, a diagram or drawing representing a magnitude upon a plane surface.

Figure of the Earth.—The shape or form of the globe on which we live; it is found to be an oblate spheroid, the axis of which coincides with the axis of the Earth. The terrestrial elements, as found by the United States Corps of Topographical Engineers, are as follows:

Equatorial radius,	6377397·15 metres.
Polar "	6356078·96 "
Eccen. of meridian,	0·0816967.

The metre employed in these elements is taken equal to 39·36850154 American standard inches, as determined by Hassler in 1832. These elements are those at present used upon the coast survey. Reduced to yards, the elements are—

Equatorial radius	=	6974532·339 yards.
Polar "	=	6951218·059 "
Eccen. of meridian	=	0·0816967.
Ellipticity	=	$\frac{1}{299·66}$

The following are the elements of the Earth's figure as given by Bessel and Airy:

Bessel.

	Feet.		Miles.
Eq. radius,	20923596	=	3962·802
Polar "	20853662	=	3949·557
Ellipticity,	$\frac{1}{299 \cdot 15}$		

Airy.

	Feet.		Miles.
Eq. radius,	20923713	=	3962·824
Polar "	20853810	=	3949·585
Ellipticity,	$\frac{1}{299 \cdot 33}$		

Davies's and Peck's Math. Dict.

Filar-micrometer.—See MICROMETER.

Finder.—A small telescope, having a low power and a large field of view, attached to the larger telescope. The finder and the large telescope should have their axes parallel to each other.

Firmament.—The sphere of the fixed stars.

First Quarter.—When the Moon is 90° distant from the Sun after *new moon*, she is in her first quarter.

Fixed Stars.—Those bodies which do not belong to the solar system. They generally retain the same position and distance with respect to each other.

Flora.—The eighth asteroid; it was discovered by Hind, October 18, 1847.

Focal Distance.—The distance from the focus of an ellipse to the nearest extremity of the transverse axis.

Focal Length.—The distance of the image of the object from the object-glass is called the focal length of the telescope. This is commonly a little greater than the length of the main tube.

Foci of an Ellipse.—Two points in the major axis, such that the sum of the two lines drawn from them to any point in the ellipse is equal to the major axis.

Focus.—That point in which several rays meet after having been either reflected or refracted.

Focus of a Mirror.—The focus of a concave mirror is a point distant from its surface equal to one-half of the radius of the sphere of which the mirror is an arc.

Following.—See NORTH FOLLOWING.

Fomalhaut.—A star of the first magnitude in the constellation Piscis Australis. It is also known as α Piscis Australis.

Force.—That which is the cause of motion; power.

Force, Accelerative.—That power which accelerates the velocity of motion.

Force, Motive.—Otherwise called *momentum*, which see.

Force, Retardive.—That power which retards the velocity of motion.

Forestaff.—An instrument formerly used to take the altitudes of the heavenly bodies. With the forestaff the observer stood with his face to the object observed, while with the *backstaff* the back of the observer was turned to the object.

Formed Stars.—Those stars which are arranged under certain figures called constellations.

Fornax Chemica.—A southern constellation, the middle of which is R. A. 3*h.* 0*m.*, Dec. 30° S.

Fortuna.—The nineteenth asteroid; it was discovered by Hind, August 22, 1852.

Frigid Zone.—The space of 23° 28′ about each pole. The Arctic Circle is the boundary of the north frigid zone, and the Antarctic Circle the boundary of the south frigid zone.

Frustrum.—A part of some solid body separated from the rest. The *frustrum of a cone* is that part which remains when the top is cut off by a plane parallel to the base: it is otherwise called a truncated cone.

Galaxy, (*γαλακτος, milk.*)—A whitish, luminous band, of irregular form, which is seen on a dark night stretching across the heavens. It contains myriads of stars, so crowded together that their united light only reaches the unassisted eye. It is also known by the names of the *Milky Way* or *Via Lactea.*

Gassendi.—A spot on the surface of the Moon known by this name.

Gauging.—The estimation of the number of visible stars in any field of view of a telescope; a term used by Sir W. Herschel to signify the penetration into space with instrumental power.

Gemini.—One of the zodiacal constellations, the middle of which is R. A. 7*h.* 20*m.*, Dec. 25° 0′ N.

Gemma.—See ALPHECCA.

Geocentric.—Having the Earth for the centre. Properly speaking, the Moon alone is geocentric.

Geocentric Diameter.—The diameters of the Sun, Moon, or planets, as seen from the centre of the Earth. It is the same as *vertical diameter.*

Geocentric Latitude.—See LATITUDE.

Geocentric Longitude.—See LONGITUDE.

Geocentric Parallax.—The apparent change of place of a body arising from a change of a spectator's station from the surface to the centre of the Earth.

Geocentric Place.—The place of a planet as it appears from the Earth; a point in the ecliptic to which a planet, seen from the Earth, is referred.

Geodesical Determination of the Situation of two Observatories, or other Points, with respect to each other.—The determination of their respective situations by means of triangular measurements. See GEODESY.

Geodesy.—That part of geometry which has for its object the determination of the magnitude and figure of the Earth, or any portion of its surface; land surveying.

Georgium Sidus.—See URANUS.

Ghost.—The image of a dot made to fall on a certain point or stroke of a graduated instrument. This image is created by means of an optical contrivance, the invention of Mr. Ramsden.

Giauzar.—A star in the constellation Draco, called also λ Draconis.

Gibbous.—The Moon is said to be *gibbous* when more than the half, and less than the whole, of her enlightened disc is visible to us. The same term is applied to the planets Mercury, Venus, and Mars, when presenting the same appearance.

Giedi.—The name of a quintuple star in the constellation Capricornus, also known as α Capricorni.

Gienah.—A star in the constellation Cygnus, also called ε Cygni.

Globe.—A round or spherical body, more usually called a sphere, bounded by one uniform convex surface, every point of which is equally distant from a point within, called its centre.

Globe, Artificial.—Artificial globes are either terrestrial or celestial. The *terrestrial* globe is made of paper, pasteboard, &c., and on the surface is a map representing the various portions of the Earth's surface. The *celestial* globe is a map or representation of the concave surface of the heavens, with the constellations and principal fixed stars.

Gnomon.—An instrument used by the ancients in astronomical observations. It consisted of a perpendicular staff or pillar, the shadow of which indicated the altitude of the Sun. The term is now applied to the finger of a sundial.

Golden Number.—See CYCLE OF THE MOON, or METONIC CYCLE.

Gomeisa.—A star in the constellation Canis Minor, generally known as β Canis Minoris. This star was also called *Al-Mirzam* by the Arabs.

Goniometry, (*γωνια, angle,* and *μετρον, a measure.*)—The art of measuring angles, either on the surface of the Earth or upon any plane surface.

Graduation.—The art of dividing a scale or arc of a circle into any number of equal parts.

Graffias.—See AKRAB.

Graphometer, (*γραφω, to describe,* and *μετρον, a measure.*)—An instrument used for measuring angles whose vertices are at its centre.

Gravitation, or Universal Gravity.—That power by which all the bodies and particles of matter in the universe tend towards one another.

Gravity, Centre of.—See CENTRE.

Great Bear.—See URSA MAJOR.

Great Circles.—See CIRCLE.

Gregorian Calendar.—The calendar used at the present time, commenced by Pope Gregory XIII. in 1582.

Gregorian Epoch.—The epoch or time from which the Gregorian calendar or computation took place.

Gregorian Telescope.—An instrument invented by James Gregory. See TELESCOPE.

Gregorian Year.—The year reckoned according to the new style introduced by

Pope Gregory in the year 1582, and from whom it took its name.

Grus.—A southern constellation, the middle of which is R. A. 22*h.* 0*m.*, Dec. 45° S.

Guards.—This term is applied to the stars β and γ in the constellation Ursa Minor.

Halo.—See CORONA.

Hamel.—A star called also α Arietis, situated in the constellation Aries.

Harvest Moon.—The full moon which occurs nearest to the autumnal Equinox.

Head.—The nucleus and coma of a comet are frequently included under the general term *head.*

Heavens.—The blue vault of the sky in which the heavenly bodies are situated.

Hebe.—The sixth asteroid; it was discovered by Hencke, July 1, 1847.

Heka.—A name given to a star in the constellation Orion, generally called λ Orionis.

Heliacal, (Ηλίος, *the Sun.*)—Pertaining to the Sun.

Heliacal Rising and Setting of a Star.—The rising when the Sun rises, and setting when he sets.

Heliocentric.—As seen from, or having relation to, the centre of the Sun.

Heliocentric Latitudes and Longitudes.—The latitudes and longitudes of the planets as they would appear if seen from the Sun.

Heliocentric Parallax.—The arc of a great circle of the celestial sphere drawn from the heliocentric to the geocentric place of a body. It is the path a body would appear to describe to an observer who would travel from one extremity to the other of the Earth's radius vector.

Heliocentric Place of a Planet.—The place a planet would appear to occupy if viewed from the Sun; or the point of the ecliptic in which a planet would appear to be if seen from that luminary.

Heliometer, (Ηλιος, *the Sun,* and *μετρον, a measure.*)—An instrument used for measuring the diameter of the Sun, Moon, and planets.

Heliostat, (*ἡλιος, the Sun,* and *στατος, to stand still.*)—An instrument so contrived that a reflected ray of light may be retained in a fixed position, notwithstanding the apparent motion of the Sun.

Hemisphere, (Ημι, *a half.*)—Half a globe or sphere; every great circle divides the globe into two hemispheres.

Hercules.—One of the northern constellations, the middle of which is R. A. 16*h.* 48*m.*, Dec. 30° 0′ N.

Herschel.—See URANUS.

Heteroscii, (from *ἑτερος, another,* and *σκια, a shadow.*)—All the inhabitants of the Earth, except those of the torrid zone, are called heteroscii, because their shadows at noon are always projected the same way; that is, towards the poles.

High Water.—That state of the tides when they have flowed to their greatest height.

Higher Apsis.—See APSIS.

Hircus.—See CAPELLA.

Homam.—A star in the constellation Pegasus, called also ζ Pegasi.

Horary, (*hora,* an hour.)—Relating to hours.

Horary Circles.—Those circles on the artificial globe which are drawn at the distance of an hour from each other, to mark the hours.

Horary Motion.—The motion or space moved by a heavenly body in an hour.

Horizon, (*ὁριζω, to bound.*)—The boundary to the view on all sides. The horizon is either *real* or *rational,* or *sensible* or *apparent.*

Horizon, Artificial.—An instrument having a reflecting plane situated at right angles to a perpendicular line. This is also called a *portable* horizon.

Horizon, Poles of.—The zenith and nadir are the two poles of the horizon, each being 90° distant from it.

Horizon, Portable.—See HORIZON ARTIFICIAL.

Horizon, Real or Rational.—That horizon whose plane is supposed to pass through the centre of the Earth; and which, therefore, divides the globe into two equal portions or hemispheres.

Horizon, Sensible or Apparent.—That circle which divides the visible part of the Earth and heavens from that which is

invisible; the circle which bounds the view on all sides.

Horizontal.—Level or parallel with the horizon.

Horizontal Distance.—That distance of two objects from each other estimated in the plane of the horizon.

Horizontal Parallax.—A parallax which is in the plane of the horizon. See PARALLAX.

Horizontal Plane.—A plane parallel to the horizon of a given place.

Horizontal Point.—That point on the limb of a graduated circle coincident with the plane of the horizon. The chief points of the horizon are the *north, south, east,* and *west* points.

Horizontality.—The horizontality of the axis of a transit instrument is the adjustment by means of the spirit-level, causing the axis of the instrument to be exactly in the plane of the horizon.

Horns of the Moon.—The Moon is said to be horned when her visible enlightened disc is in the form of a crescent. The points or extremities of the crescent are called the *horns.*

Horologium.—A southern constellation, the middle of which is situated R. A. 2*h.* 40*m.*, Dec. 55° 0′ S.

Hour, (*ὥρα, hour,* which is derived from the Egyptian *Horus,* a name given to the Sun, as being the father of *Hours.*)—It is the twenty-fourth part of a natural day. The Egyptians, and afterwards the Greeks, divided their day into twelve hours; this is the most ancient division of the day.

Hour Angle (Instrumental) of an Object.—The angular distance of an object from a vertical plane passing through the polar axis, and estimated upon the hour circle.

Hour Circle.—See CIRCLE.

Hour, Sidereal.—The twenty-fourth part of the interval of time between two consecutive passages of a fixed star over the meridian of a place.

Hour, Solar.—The twenty-fourth part of the time between two consecutive passages of the Sun over the meridian of a place.

Humboldt.—The name of a mountain on the Moon.

Hyades.—A cluster of stars in the constellation Taurus. The ancients supposed their rising and setting to be attended by rain or storms: thus, Horace calls them *tristes* hyades; Virgil, *pluvias* hyades; and Claudian, *nimbosas* hyades.

Hyadum Primus.—A star in the group of the Hyades, and belonging to the constellation Taurus. It is also called γ Tauri.

Hyadum Secundus.—A star in the constellation Taurus, and group of the Hyades, also known as δ Tauri.

Hydra.—A southern constellation, the middle of which is situated R. A. 10*h.* 40*m.*, Dec. 13° S.

Hydrus.—A southern constellation, the middle of which is R. A. 1*h.* 52*m.*, Dec. 66° 0′ S.

Hygeia.—The tenth asteroid; it was discovered in the year 1849, by Gasparis.

Hyperion.—The seventh satellite of Saturn; it was discovered by Bond, and afterwards by Lassel, in September, 1848.

Immersion.—When a satellite suffers eclipse, the act of passing *into* the shadow, or disappearing behind the primary, is called *immersion.* Also, when a star or planet comes so near the Sun as to be obscured by his rays.

Impetus.—Force, momentum.

Incidence or **Line of Incidence.**—The direction or inclination in which one body strikes or acts on another.

Incidence, Angle of.—The angle comprehended between the line of incidence and a perpendicular to the body acted upon.

Inclination.—The angle which one plane makes with another.

Inclination of the Axis.—The angle which the axis of a planet makes with its orbit.

Inclination of an Orbit.—The angle which the orbit makes with the ecliptic.

Incommeasurable Distance.—A distance which cannot be determined either by direct measurement or by calculation.

Index of Refraction.—The constant ratio which exists between the sines of the angles of incidence and refraction.

Indiction.—An epoch or manner of count-

ing time among the Romans, which was introduced by the Emperor Constantine in place of the Olympiads. It contains a cycle of 15 years. To find the indiction, add 3 to the given year of Christ, divide the sum by 15, and the remainder will be the year of the indiction. If there be no remainder, the indiction is 15.

Indus.—A southern constellation, the middle of which is in R. A. 21*h.* 20*m.*, Dec. 60° 0′ S.

Inequalities of the Moon.—Certain irregularities of the Moon's motion, caused by the combined attraction of the Sun and Earth, the principal of which are *equation of the centre, evection, variation,* and *annual equation.*

Inequalities, Secular.—Certain small irregularities in the motions of the planets, which become important only after the lapse of centuries.

Inequality, Great.—The variation in the orbital positions of Jupiter and Saturn, caused by their disturbing action on each other. It passes through all its changes of magnitude in about 918 years.

Inertia.—See Vis Inertia.

Inferior Conjunction.—The conjunction of the planets Mercury or Venus with the Sun at the time they are between that luminary and the Earth.

Inferior Meridian.—That half of the meridian below the horizon.

Inferior Planets.—The same as the interior planets.

Informed Stars.—See Sporades.

Ingress.—The Sun's entrance into one of the signs. In transits of Venus or Mercury it is the entrance of the planet on the Sun's disc.

Intensity of Light.—The degree of brilliancy of a planet or comet expressed as a number varying with the distance of the body from the Sun and Earth.

Irene.—The fourteenth asteroid; it was discovered by Hind, May 19, 1851.

Iris.—The seventh asteroid; it was discovered by Hind, August 13, 1847.

Irresolvable Nebulæ.—Nebulæ which appear to be too distant for our telescopes to resolve into stars, but which have a faint cloud-like appearance.

Intercalary.—A term signifying any portion of time added to the year to adjust it to the course of the Sun: thus, the odd day inserted in Leap year is called the *intercalary day.*

Interior Planets.—Those planets whose orbits are within that of the Earth.

Izar.—A star in the constellation Boötes, also called ε Boötis.

January.—The first month in the year. So called by the Romans from Janus, one of their divinities, who had two faces; because on the one side the first day of this month looked towards the new year, and on the other towards the old one. Others think it derives its name from *Janua,* a gate or door, it being the opening of the year.

Japetus.—The eighth satellite of Saturn; it was discovered by Dominic Cassini in October, 1671.

Jovicentric.—As viewed from, or relating to, the centre of Jupiter.

Julian Calendar.—That depending on the Julian year and account of time; it is so called from Julius Cæsar, by whom it was established.

Julian Epoch.—That period of the Julian calendar which began the forty-sixth year before Christ.

Julian Period.—A cycle of 7980 years, invented by Scaliger. It is formed by multiplying together the cycles of the Sun, Moon, and the indiction. The Julian period dates from the year 4713 B. C.

Julian Style.—The mode of reckoning instituted by Julius Cæsar, in which every year divisible by 4 without a remainder consisted of 366 days, and all others of 365. The same as *Old Style.*

June.—The fourth month in the old Roman year, and the sixth in our year. By the ancient Romans it was called Junius, in honor of the youth of Rome who served then in war. Some suppose it to be called in honor of Junius Brutus. On the 21st of this month the Sun enters Cancer.

Juno.—The third asteroid.

July.—The seventh month in the year. It was so named by Mark Antony, in honor of Julius Cæsar, who was born in this

month. On the 21st day of this month the Sun enters Leo.

Juno.—One of the asteroids, discovered by Harding, September 1, 1804. It is the third in order of discovery.

Jupiter.—The largest known planet of our system, situated next within the orbit of Saturn.

Kaus.—The *bow*. This name is given to the stars δ ε and λ in the constellation Sagittarius.

Kalpeny.—A star in the constellation Aquarius, marked β Aquarii on the catalogues. It is also called *Sa'd-as-suud.*

Kaphra.—A star in the constellation Ursa Major, also called κ Ursæ Majoris.

Keid.—The name of 40 Eridani, a star in the constellation Eridanus.

Kepler.—The name of a lunar mountain.

Kepler's Laws.—Those laws of the planetary motions discovered by Kepler. The first two were announced by their author in 1609, and the third in 1618.

Kitalpha.—A name given to the star in the constellation Equüleus, known also as α Equülei.

Kochab.—An Arabic name given to the star β Ursæ Minoris, in the constellation Ursa Minor.

Korneforos.—A bright star in the constellation Hercules, also known as β Herculis.

Lacerta.—A northern constellation, the middle of which is R. A. 22*h.* 28*m.*, Dec. 45° 0′ N.

Last Quarter.—When the Moon is 90° distant from the Sun, after *full moon*, she is in her last quarter.

Latitude, Geocentric.—The angle included between the radius of the Earth through the place on its surface, and the plane of the equator. The geocentric latitude is always a little less than the geographic latitude.

Latitude, Heliocentric.—The latitude of a star or planet as seen from the Sun.

Latitude of the Moon, North Ascending.—When the Moon proceeds from the ascending node towards her northern limit.

Latitude of the Moon, North Descending.—When the Moon returns from her northern limit towards her descending node.

Latitude of the Moon, South Ascending.—When the Moon returns from her southern limit towards her ascending node.

Latitude of the Moon, South Descending.—When the Moon proceeds from her decending node towards her southern limit.

Latitude of a place on the Earth.—The distance of a place from the equator, reckoned on an arc of the meridian towards the north or south pole.

Latitude, Reduction of.—The difference between the latitude and the central latitude.

Latitude of a Star or Planet.—Its distance from the ecliptic, reckoned from thence north or south towards the poles of the ecliptic.

Lagging of the Tides.—See TIDES.

Leap Year.—See BISSEXTILE.

Lens.—A transparent substance of a different density from the surrounding medium, having its two surfaces so formed that the rays of light in passing through it shall have their direction changed. Lenses are of two kinds—viz.: *convex* and *concave*. Convex lenses are always thicker in the middle and thinner at the edges; and concave lenses are thinner in the middle and thickest at the edges. Convex lenses are of two kinds—*plano-convex*, having one surface plane or flat and the other spherical or convex; and *double convex*, having both sides spherical or convex. Concave lenses are also of two kinds—namely, *plano-concave*, having one side plane and the other surface concave; and *double concave*, having both surfaces concave. The *meniscus* lens is convex on one surface and concave on the other; the *concavo-convex* lens is, like the meniscus, concave on one surface and convex on the other, but the convex surface is the arc of a smaller sphere than the concave side. Lenses are usually formed of glass; but they may be made of diamond, rock, crystal, or fluids of different densities and refractive powers, enclosed between glass of a proper form.

Leo.—One of the zodiacal constellations, the middle of which is in R. A. 10*h*. 20*m*., Dec. 15° N.

Leo Minor.—A northern constellation, the middle of which is situated in R. A. 10*h*. 12*m*., Dec. 35° N.

Lepus.—A southern constellation, situated R. A. 5*h*. 20*m*., Dec. 18° S.

Lesuth.—A star of the third magnitude in the constellation Scorpio, known also as λ Scorpii.

Leucothea.—The thirty-fifth asteroid; it was discovered by Luther, April 19, 1855.

Level.—An instrument which indicates the line parallel to the horizon, by means of a bubble of air enclosed with some fluid in a glass tube of an intermediate length, and hermetically sealed. This is called the *air-level* or *spirit-level*. There are various kinds of levels, as the water-level, pendulum-level, &c. A surface is said to be level when it is concentric with the surface of the sea, or with the surface the ocean would have were the globe entirely covered with water.

Level Error.—The deviation of the axis of an instrument from the horizontal position.

Libra.—One of the zodiacal constellations, the middle of which is R. A. 15*h*. 4*m*., Dec. 8° S.

Libration in Latitude.—The axis of the Moon is not quite perpendicular to her orbit, which enables us to see sometimes a little more of her polar regions than at others. This variation is called *libration in latitude*.

Libration in Longitude.—The motion of the Moon round the Earth is not uniform; hence we see occasionally a little farther round each limb sometimes than at others, which is called the Moon's *libration in longitude*.

Libration, Parallactic.—That variation which takes place in the visible portion of the Moon's surface, caused by a change of place in the observer's point of view, produced by the Earth's rotation.

Light.—That principle by whose agency we derive our sensations of external objects through the sense of sight.

Limb.—The border or edge of the Sun or Moon, as the upper limb or edge, the lower limb, &c. It also signifies the graduated edge of a quadrant or other mathematical instrument.

Limit.—The limit of a planet is its greatest heliocentric latitude. Also, the greatest distance at which a moon can be from her nodes in order that an eclipse may occur. See Ecliptic Limits.

Limiting Parallels.—Those parallels of latitude beyond which occultations of fixed stars by the Moon cannot occur.

Line of Apsides or Apses.—A straight line joining the apses of a planet.

Line of Collimation.—See Collimation.

Line of Incidence.—In catoptrics, or the science explaining the laws of light reflected from mirrors, speculæ, &c., the line of incidence is the right line in which light is propagated from a radiant point to a point on the surface of the mirror. This line is also called an *incident ray*.

Line of the Nodes.—The imaginary line joining the nodes of a planet or satellite.

Longitude of Ascending Node.—The longitude of the Moon or a planet when in the plane of the ecliptic, moving northward.

Longitude, Celestial.—The longitude of a star or planet is its distance reckoned on the ecliptic eastward, from the point Aries, quite round the globe.

Longitude of Epoch.—See Epoch.

Longitude, Geocentric.—The longitude of a planet as seen from the Earth.

Longitude, Heliocentric.—The inclination to the plane of the ecliptic of the line drawn between the centre of the Sun and that of the planet.

Longitude, Mean.—The mean or circular motion of a body estimated from the vernal equinox.

Longitude of Perihelion.—The longitude of the perihelion is the same as the longitude of a planet when at its least distance from the Sun.

Longitude of a Star or Planet.—Its distance reckoned on the ecliptic, from the point Aries, eastward round the celestial globe.

Longitude Stars.—Those fixed stars which

have been selected for the purpose of finding the longitude by lunar observations, as *a Arietis, Aldebaran, &c.*

Longitude of the Sun.—The same as the *Sun's place* in the ecliptic—that is, the number of degrees and minutes from the point Aries.

Longitude, Terrestrial.—The distance of any place from any fixed meridian. Longitude on the Earth may be either east or west, as the place may be east or west from the fixed meridian, and is reckoned on the equator half round the globe, or 180°.

Longitude, True.—The elliptical motion of a body reckoned from the vernal equinox.

Lower Apsis.—See Apsis.

Lucida.—The principal star in a constellation.

Luculi.—The same as *faculæ,* which see.

Luminary.—That which diffuses light; a luminous body.

Lunar Cycle.—A period of time consisting of 19 years.

Lunar Distance.—The angular distance of the centre of a celestial object from the centre of the Moon.

Lunar Mountains.—Those protuberances on the Moon's surface which are visible by means of a telescope.

Lunar Observation.—A method of ascertaining the longitude at sea by the Moon's motions, particularly by her observed distances from the Sun and stars.

Lunarians.—The inhabitants (if any) of the Moon.

Lunation.—The period or time between one new moon and another; it is also called a synodical month.

Luni-solar Precession in Longitude.—The motions due to the action of the Sun and Moon when estimated on the ecliptic.

Lupus.—A southern constellation, situated in R. A. 15*h.* 20*m.*, Dec. 45° S.

Lutetia.—The twenty-first asteroid; it was discovered by Goldschmidt, November 15, 1852.

Lynx.—A northern constellation, the middle of which is R. A. 7*h.* 24*m.*, Dec. 50° N.

Lyra.—A northern constellation, the middle of which is in R. A. 18*h.* 44*m.*, Dec. 38° N.

M.—In the astronomical tables M is used for meridional or southern; also for midday.

Machina Pneumatica or **Antlia Pneumatica.**—A southern constellation, the middle of which is R. A. 10*h.* 0*m.*, Dec. 35° S.

Maculæ.—Dark solar spots, surrounded by a band or border less completely black, called a penumbra.

Magnetic Amplitude.—An arc of the horizon intercepted between the Sun in his rising or setting and the east and west points of the compass.

Magnetic Meridian.—See Meridian.

Magnetic North.—The direction of the magnetic meridian which passes through the magnetic poles and the place of the observer.

Magnifying Power.—The amount of apparent enlargement of an object by means of a lens.

Magnitude.—That which is made up of parts locally extended, as a line, surface, or solid. The stars are said to be of the first, second, third, &c. magnitude, according to their brilliancy, without reference to their real size, which is unknown.

Magnitude, Apparent.—The visual angle formed by rays drawn from the extremities of a body to the centre of the eye.

Magnitude of an Eclipse.—The proportion which the eclipsed portion of the disc of the Sun or Moon bears to the diameter. It is sometimes expressed in *digits,* but more frequently as a decimal, the diameter being taken as unity.

Maia.—A name given to one of the Pleiades.

Major Axis.—See Axis.

Malus.—One of the divisions of the constellation Argo Navis, as made by some astronomers. It signifies the *mast.*

Manilius.—The name of a lunar mountain.

Map.—A representation on a plane surface of a portion of the heavens, or of the surface of the Earth; the former is called a *celestial,* the latter a *terrestrial,* map.

March.—The third month in the year, according to our calendar; but in the old Roman year it stood first, in honor of Mars.

Mare Crisium.—A name designating a flat portion of the Moon's sphere. It was

called *mare* because it was formerly thought to be a *sea*.

Mare Humorum.—A spot on the surface of the Moon designated by the name of a sea.

Marfak.—A name given by the Arabians to the stars μ and θ in the constellation Cassiopeia.

Markab.—A bright star in the constellation Pegasus, forming the south-eastern corner of the *Square.* It is also known as α Pegasi.

Markeb.—A small star in the constellation Argo Navis, marked κ Argo Navis.

Mars.—The fourth planet in order from the Sun.

Marsik.—A binary star in Ophiuchus, also known as λ Ophiuchi.

Mass.—The entire amount of matter contained in a body; the weight or attractive power of a planet expressed in reference to that of the Sun.

Massilia.—The twentieth asteroid in order of discovery. It was seen by Gasparis, at Naples, on the 19th of September, 1852; and by Chacornac, at Marseilles, on the following evening, the 20th of September.

Masym.—A star in the constellation Hercules, known as λ Herculis.

Matter.—That which is the object of our senses.

Maximum.—The greatest quantity or degree attainable in any given case.

May.—The fifth month in our year, but the third month according to the ancient Roman reckoning. It was called Maius by Romulus, in respect to the senators and nobles of Rome, who were called Majores. Some say it was thus called from Maia, the mother of Mercury, to whom they offered sacrifice on the first day of this month.

Mean.—A middle state between two extremes.

Mean Distance of a Planet from the Sun.—An arithmetical mean between the planet's greatest and least distances, and this is equal to the semi-transverse axis of the elliptical orbit in which it moves.

Mean Equinox.—The estimated place of the vernal equinox without nutation.

Mean Equinox, Reduced Place of.—The intersection of a declination circle through the mean equinox with the equinoctial.

Mean Motion.—The mean angular velocity of a body. The rate at which a body moving in an elliptic orbit would proceed, had it to describe the whole circumference at an equal velocity throughout.

Mean Noon.—The time of the mean Sun being on the meridian of a place.

Mean Obliquity.—The inclination of the equinoctial to the ecliptic without nutation.

Mean Sidereal Time.—Time measured by the hour-angle of the mean equinox.

Mean Solar Time.—That time which is indicated by our clocks and watches, which is regulated by the motion of an imaginary Sun supposed to move uniformly in the equator. See MEAN SUN.

Mean Sun.—Astronomers assume the revolution of a sun in a circular orbit in the plane of the equator, having the mean diurnal motion in right ascension of the true Sun. The time which elapses between two successive transits of the mean Sun constitutes a mean solar day, which is the measure of time in common use.

Mean Time.—That time which is measured by any equable motion, as that of a clock.

Medium.—The space in which a ray of light moves; it may be either pure space, air, water, glass, diamond, or any other transparent substance through which rays of light can pass in straight lines.

Medium Cœli.—Mid-heaven.

Medium, Resisting.—A thin ethereal matter, supposed to pervade all space, and which resists the progressive motions of the periodical comets, so that their velocity is diminished, and consequently their orbits contracted, at every revolution.

Megallanic Clouds.—See NUBECULÆ.

Megaloscope.—A species of telescope for viewing objects which are very near.

Megrez.—A star in the constellation Ursa Major, called also δ Ursæ Majoris.

Melpomene.—The eighteenth asteroid; it was discovered by Hind, June 24, 1852.

Menchib.—A star in the constellation Perseus, called also ξ Persei.

Menkalinan.—A star in the constellation Auriga, called also β Aurigæ.

Menkar.—A star in the constellation Cetus, also called α Ceti.

Menstrual Argument of Latitude.—See ARGUMENT.

Merak.—A bright star in the constellation Ursa Major, known as β Ursæ Majoris. This star is one of the *Pointers.*

Mercury.—The planet nearest to the Sun, around which it is carried with a very rapid motion. Hence the Greeks called this planet Mercury, after the name of the nimble messenger of the gods.

Meridian.—A great circle of the sphere passing through the zenith and the poles. It is so called from the Latin *meridies*, midday, because when the Sun is on the meridian it is noon to all places situated under it.

Meridian Altitude.—An arc of the meridian intercepted between the horizon and the centre of an object on the meridian.

Meridian Line.—The intersection of the plane of the meridian with the sensible horizon.

Meridian, Magnetic.—The intersection of the surface of the Earth with a vertical plane passing through the magnetic poles and the given place.

Meridian Mark.—A mark on a pillar, or some fixed object in the line of the meridian, and situated at a proper distance from the observatory.

Meridian Passage.—The transit of a planet over the meridian of any place.

Meridian, Plane of.—An imaginary surface supposed to pass through the meridian and to be extended to the celestial sphere.

Meridian, Rational.—The intersection of the rational horizon with the meridian plane of the place.

Meridian, Terrestrial.—A line passing through the poles of the Earth, all the points of which line have contemporaneously the same noon.

Meridian Transit.—The passage of a heavenly body across the meridian.

Merope.—One of the Pleiades.

Mesartim.—A star in the constellation Aries, known also as γ Arietis.

Meteor.—A fiery or luminous body occasionally seen moving rapidly through the atmosphere, sometimes leaving behind it a luminous train of light, which continues for several seconds. Meteors are vulgarly called *falling stars*, or *shooting stars.*

Meteoric Stones or **Meteorites.**—Stones or semi-metallic substances which fall from the upper regions of the atmosphere.

Metis.—An asteroid discovered by Graham, April 25, 1848, and is the ninth in order of discovery.

Metonic Cycle.—A cycle of 19 years, so called from Meton, the Athenian, by whom it was discovered. See CYCLE OF THE MOON.

Miaplacidus.—A star of the first magnitude in the constellation Argo Navis, called β Argo Navis.

Micrometer, (*μικρος, small,* and *μετρον, a measure.*)—An astronomical instrument to measure small angular distances.

Micrometer, Position.—A micrometer having a single thread or wire, which is carried round, by a smooth revolving motion, in the common focus of the object and eye-glasses, and in a plane perpendicular to the axis of the telescope. It is used to determine the situation of two fixed stars with regard to each other, if they both appear in the field of the telescope at the same time.

Microscopium.—A southern constellation, the middle of which is R. A. 20*h.* 40*m.*, Dec. 38° S.

Midday, Noon.—That point of time when the Sun is on the meridian of a given place.

Mid-heaven or **Medium Cœli.**—That point of the ecliptic which culminates, or is on the meridian, at any time. See also NONAGESIMAL.

Midnight.—That point of time opposite to noon. At midnight the Sun is on the meridian 180° from us.

Milky Way.—See GALAXY.

Mimas.—The innermost or first satellite of Saturn; discovered by Sir William Herschel, September 17, 1789.

Minimum.—The least quantity.

Minor Axis.—The shorter or conjugate diameter of the ellipse, and perpendicular to the longer or transverse diameter.

Mintaka.—The name of a star of the second magnitude in Orion's belt. It is also known as δ Orionis.

Minute.—The sixtieth part of an hour; and also the sixtieth part of a degree of angular measurement.

Mira, (*mirabilis,* wonderful.)—A variable star in the neck of Cetus, also called *o* Ceti, or sometimes Collo Ceti. It passes through all its changes in 334 days, during which time it exhibits some remarkable irregularities.

Mirach.—A star in the constellation Andromeda, known as β Andromedæ.

Mirfak.—An Arabic name for a star in the constellation Perseus, known also as α Persei.

Mirror.—The surface of an opaque body polished and fitted to reflect the rays of light that fall upon it; a looking-glass.

Mirzam.—A star in the constellation Canis Major, known as β Canis Majoris.

Mizar.—A bright star in the constellation Ursa Major, also called ζ Ursæ Majoris.

Mock Sun.—See Parhelion.

Momentum.—The onward impulse or force of motion of a body.

Monoceros.—A southern constellation, the middle of which is R. A. 7*h.* 20*m.*, Dec. 0° S.

Mons Menalus.—A northern constellation, the middle of which is R. A. 14*h.* 40*m.*, Dec. 15° N.

Mons Mensæ.—A southern constellation, the middle of which is R. A. 5*h.* 20*m.*, Dec. 75° S.

Month, (Saxon, *monath,* and Teutonic, *Mond,* the Moon.)—The twelfth part of the year, and is so called from the Moon, by whose motions it is regulated, being properly the time which the Moon moves through the zodiac.

Month, Anomalistic.—The time the Moon requires to move from perigee and return to that point again.

Month, Nodical.—The time occupied by the Moon in completing a revolution from one node to the same node again.

Month, Solar.—The time in which the Sun appears to move through one sign of the zodiac.

Month, Synodic.—Called also a lunation. See Lunation.

Moon.—The satellite belonging to our Earth.

Moon-culminating Stars.—Those stars which, being near the Moon's parallel of declination, and not differing much from her in right ascension, are proper to be observed with the Moon, in order to determine the differences of meridians.

Moon, Full.—That appearance of the Moon when she is in opposition to the Sun, or when her full orb shines on us.

Moon, New.—That phase of the Moon which happens when she is in conjunction with the Sun.

Motion.—A continued and successive change of place.

Motion, Absolute.—An absolute change of place considered independently of any other body.

Motion, Accelerated or **Retarded.**—That motion, the velocity of which is continually increased or diminished.

Motion, Angular.—That motion by which the angular position of any body is changed.

Motion, Compound.—That motion produced by two or more powers acting in different directions.

Motion, Direct.—A planet's motion is said to be direct when it moves in its orbit from west to east, or according to the order of the signs.

Motion, Diurnal.—The angular motion described by a heavenly body in twenty-four hours.

Motion, Equable or **Uniform.**—That motion by which a body proceeds with exactly the same velocity, always passing over equal spaces in equal times.

Motion, Horary.—That motion which takes place during an hour.

Motion, Proper.—Change of place of the fixed stars is called their *proper motion.* This term is also applied to the motion of a planet from west to east, or according to the order of the signs.

Motion, Relative.—The change of the relative place of a moving body with regard to another body also in motion.

Motion, Retrograde.—When the real or apparent motion of a heavenly body is from east to west, it is said to be retrograde.

Motion, Simple.—That motion which is produced by some one power or force only.

Motion, Sidereal.—The motion of the Earth or a heavenly body with respect to the fixed stars.

Motion, True.—That motion which a heavenly body actually performs.

Motion, Tropical.—The motion of a body with respect to the equinox or tropic.

Mufrid.—A star of the third magnitude in the constellation Boötes, also known as η Boötis.

Muliphien.—A name applied to a variable star in the constellation Canis Major. The stars α and β Columbæ are also called Muliphien.

Multiple Stars.—Four or more stars united together, forming one system, and revolving round a common centre of gravity.

Mural Arch, (*muralis*, a wall.)—An instrument or quadrant fixed against a wall or pillar, having its face in the plane of the meridian, for the purpose of making observations.

Mural Circle.—A graduated circle, the axis of which is placed due east and west, and firmly fixed in a horizontal position in the face of a stone pier or wall, and erected in the plane of the meridian. It is used to determine the declinations of the heavenly bodies.

Mural Quadrant.—An astronomical quadrant fixed in the plane of the meridian against a substantial *wall*. It is hence denominated a *mural* quadrant.

Musca Australis.—A southern constellation, situated R. A. 12*h.* 20*m.*, Dec. 70° S.

Musca Borealis.—A northern constellation, the middle of which is R. A. 2*h.* 40*m.*, Dec. 28° N.

Nadir.—That point of the heavens directly under the feet of an observer; that point opposite to the zenith.

Nadir, Apparent.—That point in which a plumb-line extended intersects the celestial sphere under our feet.

Nadir of the Sun.—The axis of the conical shadow projected by the Earth.

Naos.—A name given to the star ζ in the constellation Argo Navis.

Naschirah.—Another name for δ Capricorni, a star in the constellation Capricornus.

Natural Day.—The time in which the Earth rotates on its axis.

Nautical Almanac or **Astronomical Ephemeris.**—An almanac containing the latitudes, longitudes, ascensions, declinations, &c. of the heavenly bodies. It is intended for the use of mariners, as well as astronomers; and the calculations are for two or more years in advance.

Neap Tides.—Those tides which occur soon after the Moon's quadratures, or first and last quarters.

Nebula.—A collection of stars so closely congregated as to require large telescopes to separate them.—*Hind.*

Nebulæ, Double.—Those nebulæ which appear near to each other when viewed through the telescope.

Nebulæ, Irregular.—Those nebulæ which appear to be destitute of any symmetry of form.

Nebulæ, Irresolvable. — Those nebulæ which are at too great a distance for our telescopes to separate, so as to discern their component stars. Through the best instruments they appear like spots of cloudy light.

Nebulæ, Planetary.—Those nebulæ having discs resembling planets, being sometimes quite round, at others oval, with a hazy edge or outline. They are very rare, most of those yet discovered being in the southern hemisphere.

Nebulæ, Spiral.—Nebulæ which appear to consist of a spiral arrangement of stars diverging from a centre.

Nebular Hypothesis.—A theory advanced by La Place, which assumed that the nebulous matter which surrounds some stars was diffused throughout the universe, and that by its attraction and condensation this nebulous matter gradually formed clusters of stars. More recent discoveries, however, tend to show the fallacy of this theory.—*Hind.*

Nebulous Stars.—Those stars which are

surrounded by a circular disc or atmosphere of faint light.

Nebulous Double Stars.—Double stars surrounded by a faint atmosphere of light.

Nekkar.—A bright star in the constellation Boötes, and known as β Boötis.

Neptune.—The most distant known planet in our system.

Newton.—The name of an elevated peak on the Moon.

Nihal.—The name of a star in the constellation Lepus, commonly known as β Leporis.

Nocturnal Arc.—The arc of the heavens described by a celestial body in the night.

Node, Ascending.—See ASCENDING NODE.

Node, Descending. — See DESCENDING NODE.

Node, Longitude of.—The distance of the ascending node from the first point of Aries.

Nodes, (*nodus,* a knot.)—The two opposite points in a planet's orbit where it intersects the ecliptic.

Nodes, Line of.—See LINE OF NODES.

Nodus Primus.—A star situated in Draco, known also as ζ Draconis.

Nodus Secundus.—A bright star in the constellation Draco, also called δ Draconis.

Nodical Revolution.—The passage of the Moon from one node to the same node again.

Nonagesimal, called also **Mid-heaven.**—It is the highest point, or 90th degree of the ecliptic, reckoned from its intersection with the horizon.

Nonius.—A name given erroneously for *Vernier.*

Norma.—A southern constellation, the middle of which is R. A. 16*h.* 8*m.*, Dec. 50° S.

Normal.—In mathematics, another name for perpendicular.

North.—One of the four cardinal points. That point of the horizon opposite to the Sun when on the meridian at noon.

North Polar Distance.—The distance of a celestial body from the north pole of the heavens.

North Pole.—A point in the northern hemisphere of the heavens, 90° every way distant from the equinoctial.

North Following.—That portion of the quadrant situated between the north and east points.

North Preceding.—A term used to indicate a point of the quadrant between the north and west points.

North Star.—See CYNOSURA.

Northern Constellations.—See CONSTELLATIONS.

Northern Light.—See AURORA BOREALIS.

Northern Signs.—Those six signs of the zodiac which are north of the equinoctial—viz.: Aries, Taurus, Gemini, Cancer, Leo, and Virgo.

Nova.—New.—A term used by Sir J. Herschel in his catalogue, signifying stars or nebula which have never before been discovered.

November.—The eleventh month in our year, but the ninth in the Roman year, whence its name, from *Novem,* nine. About the 21st day of this month the Sun enters Sagittarius.

Nubeculæ or **Magellanic Clouds.**—Two large nebulæ near the southern pole of the equator; they are called nubecula major and minor.

Nucleus.—The solid part of any thing. The central part of the body or head of a comet.

Nutation.—A libratory motion of the Earth's axis, discovered by Dr. Bradley, by which its inclination to the plane of the ecliptic is continually varying by a small amount.

Nutation of Obliquity.—The difference between the mean and apparent obliquity of the ecliptic.

Nycthemeron.—Natural day. See DAY.

Oberon.—A name given by Sir John Herschel to the third satellite of Uranus.

Obfuscate.—To darken. During a solar eclipse the Sun is said to *obfuscate;* that is, to become obscured.

Object-glass.—The glass of a telescope or microscope which is placed at the end of the tube which is next or towards the object to be viewed.

Oblate.--Flattened.

Oblate Spheroid.—See SPHEROID.

Oblique.—Not perpendicular; inclined. An angle more or less than a right angle.

Oblique Ascension.—That point of the equinoctial which rises with the centre of the Sun or a star in an oblique sphere.

Oblique Descension.—That point of the equinoctial which sets with the centre of the Sun or a star in an oblique sphere.

Oblique Sphere.—That position of the Earth when the rational horizon cuts the equator *obliquely;* hence it derives its name. All the inhabitants of the Earth, except those who live at the poles or on the equator, have this position of the sphere; their days and nights are of unequal lengths, the parallels of latitude being divided into unequal parts by the rational horizon.

Obliquity of the Ecliptic.—The angle which the ecliptic makes with the equator.

Observatory.—A building designed for the reception of astronomical instruments, and for making observations on the heavenly bodies.

Observation.—The act of observing with an instrument some celestial phenomena, such as the altitude of the Sun, Moon, stars, &c. By this term seamen mean only taking the meridian altitudes in order to find the latitude.

Obtuse Angle.—One that is greater than a right angle, or that consists of more than 90°.

Occidental.—Westward. A planet is said to be occidental when it sets after the Sun.

Occultation.—The eclipse of a planet or fixed star by another planet or the Moon.

Occultation, Circle of Perpetual.—A circle at a certain distance from the poles which contains all those stars never seen in our hemisphere. The situation of this circle of course depends on the latitude of the observer.

Occulted.—A body is said to be occulted when it is hidden or eclipsed by another body coming between it and the observer. This term is chiefly applied to the eclipses of planets or stars by the Moon.

Octaeteris, (οκτω, *eight,* and ετος, *year.*)—A cycle or term of eight years, at the end of which three lunar months were added. This cycle was in use until Meton, the Athenian, reformed the calendar by discovering the golden number, or cycle of nineteen years.

Octans Hadleianus.—A southern constellation, situated R. A. 21*h.*, Dec. 85° S.

Octant or **Octile.**—An aspect or position of two planets, when their places are distant by the eighth part of a circle, or 45°.

October, (οκτω, *eight.*)—This is now the tenth month of the year, but was the *eighth* in the calendar of Romulus. About the 22d of this month the Sun enters Scorpio.

Olympiads.—Periods of time consisting of four Grecian years. The name is derived from Olympia, where public games were celebrated every fourth year.

Opaque Body.—One that is impervious to the rays of light; that cannot transmit light. An opaque body will cast a shadow, and receive one that is cast by some other body.

Ophiuchus, sometimes called **Serpentarius.**—The middle of this constellation is R. A. 17*h.* 8*m.*, Dec. 0° 0′.

Opposition.—A planet is said to be in opposition when its longitude differs from that of the Sun by 180°.

Optical Double Star.—See Double Star.

Optics.—That branch of natural philosophy which treats of the nature and properties of light.

Orbit.—The path of a planet or comet round the Sun, or of a satellite round its primary. The path of any heavenly body, or system of bodies, round its centre of gravity.

Orbitual.—Relating to an orbit.

Orbus Magnus.—Another name for the orbit of the Earth.

Order.—A heavenly body is said to move in the *order* of the signs when it proceeds from Aries to Taurus, thence to Gemini, &c. See Consequentia.

Orient.—The east, or eastern point of the horizon.

Oriental.—Easterly. When a planet rises before the Sun it is said to be *oriental.*

Orion, (called by the Arabians *Almahbarrah,* the brave warrior.)—A splendid southern constellation, the middle of which is in R. A. 5*h.* 20*m.*, Dec. 0°.

Orrery.—An astronomical machine for exhibiting the various motions of the Sun and planets; it was so called in honor of the Earl of Orrery, by whom the invention was first patronized: it was afterwards called a *planetarium.*

Orthogonal, (ὀρθὸς, *right,* and γονία, *an angle.*)—A term given to any figure which has one or more right angles.

Ortive Amplitude or **Eastern Amplitude.**—An arc of the horizon intercepted between the point where a star rises and the east point of the horizon.

Oscillation.—A motion to and fro like the pendulum of a clock.

Oscillation, Axis of.—A line parallel to the horizon, and supposed to pass through the point about which a pendulum oscillates; it is perpendicular to the plane in which the oscillation is made.

Palilicium.—Another name for *Aldebaran,* a bright star in the constellation Taurus; the same name was given by Pliny to the Hyades, a group of stars in the same constellation.

Pallas.—The second asteroid in the order of discovery. It was first observed by Dr. Olbers, March 28, 1802.

Parabola.—A figure arising from the section of a cone when cut by a plane parallel to one of its sides.

Paracentric, (παρα, *beyond,* and κεντρον, *centre.*)—Deviating from the centre. A curve having the property that, when its plane is placed vertically, a heavy body descending along it, urged by the force of gravity, will approach to, or recede from, a fixed point or centre, by equal distances in equal times.—*Davies and Peck, Math. Dict.*

Paracentric Motion.—A term indicating the quantity which a revolving body approaches to, or recedes from, its centre of motion or attraction.

Parallactic Angle.—See PARALLAX.

Parallactic Inequality.—An inequality in the Moon's motion arising from the sensible difference in the Sun's disturbing force, when the Moon is in that portion of her orbit nearest to the Sun, or when in the opposite point of her path.

Parallactic Libration.—See LIBRATION.

Parallactic Motion.—The motion of a body when the space described by it subtends or is seen under a sensible angle.

Parallax.—The angle under which an object is seen from the Earth. As our distance is increased, the parallax is diminished. The difference between the apparent position of the Sun, Moon, or planets, when viewed from the surface of the Earth and from its centre, is called the parallax.

Parallax, Annual.—The angle which the diameter of the Earth's orbit would subtend if viewed from one of the heavenly bodies. The change of place observable in a few of the fixed stars, which is due to the motion of the Earth round the Sun, is called the *annual parallax.*

Parallax, Diurnal.—The change of place in a heavenly body arising from the motion of the Earth upon her axis, is sometimes called the *diurnal parallax.*

Parallax, Equatorial Horizontal.—The greatest angle subtended by the Earth's equatorial semi-diameter as seen from the Sun or Moon.

Parallax, Horizontal.—The parallax of a celestial body when in the horizon. As the body rises above the horizon the parallax diminishes until it arrives at the zenith, where the parallax vanishes.

Parallel Lines, (παρα, *against,* and αλληλων, *one another.*)—Lines having the same direction; though two parallel lines were infinitely extended, they would always be equidistant from each other in all their parts.

Parallel Rays.—Those rays which are always at an equal distance, in respect to each other, from the visual object to the eye, from which the object is supposed to be infinitely distant.

Parallelism of the Earth's Axis.—The parallel position which the Earth always preserves in regard to itself in its orbit round the Sun; so that if a line be drawn parallel to its axis, while in any one part of its orbit, the axis in all other parts will be parallel to the same line.

Parallelogram, (παραλληλος, *parallel,* and γραμμα, *a diagram.*)—A quadrilateral

figure whose opposite sides are parallel and equal taken in pairs, and also its opposite angles.

Parallelogram of Forces.—A term used to denote the composition of forces, or the finding a single force that shall be equivalent to two or more given forces acting in given directions.

Parallels of Altitude.—See ALMACANTARS.

Parallels of Declination.—Lesser circles of the celestial sphere parallel to the equinoctial.

Parallels of Latitude.—In astronomy, lesser circles parallel to the ecliptic; but in geography, they are lesser circles parallel to the equator.

Parallel Sphere.—That situation of the sphere where the equator coincides with the horizon, and the poles with the zenith and nadir. This is the position of the sphere to the inhabitants, if any, at the poles.

Paraselene.—A meteor in a cloud resembling the Moon; a *mock moon.*

Parhelion or **Mock Sun.**—(*παρα, near,* and *ἥλιος, the Sun.*)—A phenomenon usually accompanying the coronæ or luminous circles which sometimes surround the Sun. The mock suns are often very bright, being formed by the reflection and refraction of the Sun's rays.

Parthenope.—An asteroid, discovered May 13, 1850, by Gasparis. It is the eleventh in order of discovery.

Partial Eclipse.—An eclipse of the Sun or Moon in which only a part of the disc is obscured.

Path.—A term applied to the curve made by any heavenly body as it moves through space.

Pavo.—A southern constellation, in R. A. 19*h.* 40*m.*, Dec. 68° S.

Pegasus.—A northern constellation, the middle of which is R. A. 23*h.* 0*m.*, Dec. 5° N.

Pencil of Rays.—A system of rays diverging from a point. A double cone or pyramid of rays diverging from some luminous point, and which, after falling on, and passing through, a lens, converges again on entering the eye.

Pendulum.—Any heavy body so suspended that it may vibrate about some fixed point by the force of gravity. The vibrations of a pendulum are called its *oscillations;* the time of each oscillation being the time required for the pendulum to pass from the highest point on one side to the highest point on the other side.

Penumbra.—In an eclipse, a faint or partial shade observed between the perfect shadow and the full light. Also, the border or margin surrounding the dark spots on the Sun.

Periaster,(*περι, around,* and *αςτρον, a star.*)—That point in the orbit of a double or compound star nearest to its primary.

Perigean Tides.—Those spring-tides which occur soon after the Moon passes her perigee.

Perigee, (from *περι, about,* and *γῆ, the Earth.*)—That point of the orbit of the Moon which is the nearest to the Earth.

Perihelion, (*περι, around,* and *ἥλιος, the Sun.*)—That point in a planet's orbit nearest to the Sun.

Perihelion Distance.—The least distance of a planet or comet from the Sun.

Perihelion, Longitude of.—See LONGITUDE.

Perihelion Passage.—The moment of time when a planet or comet is in that point of its orbit nearest to the Sun.

Perimeter, (*περι, around,* and *μετρον, a measure.*)—The sum of the boundary lines of any figure. In any circular figure, the terms *circumference* and *periphery* are used.

Period.—The time which a star, planet, or comet requires to perform one revolution round its centre of gravity; also, a series of years by which time is measured by different nations; as, the Julian, the Calippic, the Metonic, the Chaldaic period.

Period of the Eclipses.—A period of time in which the Sun and Moon will be found nearly in the same position with respect to the place of the Moon's node. This period consists of 223 lunations, or 6585 days.

Periodic.—A term applied to the motions or courses of the heavenly bodies performed within any given space of time.

Periodic Inequalities.—Those disturb-

ances in the motions of the planets which are caused by their reciprocal attraction, depending upon their positions with regard to each other, and which are accomplished in a definite period.

Periodical Month.—The time required by the Moon to perform one revolution round the Earth.

Periodic Time.—The interval between two consecutive passages of a planet through the same node.

Periodic Variation.—A regular or successive variation in the motions of the heavenly bodies.

Periœci, (*περι, about, around,* and *οικος, a house.*)—Those inhabitants of the Earth who live in the same latitude, but opposite longitudes.

Periphery, (*περι, about,* and *φερο, to carry.*)—The circumference of any curve, as the circle, ellipse, parabola, &c.

Periscii, (*περι, about,* and *σπια, a shadow.*)—The inhabitants of the frigid zones are so called because their shadows turn round to all the points of the compass in one day; for as the Sun does not set to them once in twenty-four hours, their shadows are directed to every point of the compass in that time.

Perisaturnium.—That point of the orbit of any of Saturn's satellites which is nearest to Saturn, its primary.

Perpendicular.—At right angles with. One line is perpendicular to another when the former meets the latter so as to make the angles on both sides of it equal to each other.

Perseus.—A northern constellation, the middle of which is R. A. 3*h.* 12*m.*, Dec. 48° N.

Perturbations.—Inequalities in the motions of the planets owing to their mutual attraction. Perturbations are of two kinds: periodic and secular. The former are accomplished in short spaces of time, as a few months, years, or even hundreds of years; the latter require immense periods of time, and are therefore called secular inequalities.

Petavius.—An inequality on the surface of the Moon to which this name has been given.

Phaet.—A name given to the star α in the constellation Columba.

Phases, (*φαινω, to appear,* or *shine.*)—Changes in the illuminated discs of the planets or the Moon, from the crescent to the full orb.

Phase, Greatest.—The moment when the largest portion of the disc of the Sun or Moon is obscured during an eclipse.

Phecda.—A star in the constellation Ursa Major; also termed γ Ursæ Majoris.

Phenomenon.—An extraordinary appearance in the heavens or on earth; either discovered by observation of the celestial bodies, or by physical experiments.

Pherkad Major.—A name given to the brighter of the two stars composing the double star γ Ursæ Minoris.

Pherkad Minor.—A name given to the *comes* of γ Ursæ Minoris, a star in the constellation Ursa Minor.

Phocea.—An asteroid, discovered by Chacornac April 6, 1853. It is the 25th in the order of discovery.

Phœnix.—A southern constellation, situated in R. A. 0*h.* 40*m.*, Dec. 50° 0′ S.

Photometer, (*φως, light,* and *μετρον, a measure.*)—An instrument for measuring the illuminating powers of different sources of light.

Photometry.—The science of measuring light.

Phurud.—A star in the constellation Canis Major; also called ζ Canis Majoris.

Physical Astronomy.—That department of astronomy which treats of the motions of the heavenly bodies, and the laws which operate to produce them.

Pico.—An inequality on the lunar surface to which this name is given.

Pisces.—One of the twelve zodiacal constellations, the middle of which is R. A. 0*h.* 20*m.*, Dec. 10° N.

Pisces Australis.—A southern constellation, in R. A. 22*h.* 20*m.*, Dec. 30° S.

Pisces Volans.—A southern constellation. Its R. A. is 8*h.* 22*m.*, Dec. 68° S.

Place.—That part of space occupied by any body. The place of the Sun, Moon, or a planet, is that point of the zodiac occupied by the luminary.

Place, Apparent.—That point in which a

heavenly body appears when viewed from the surface of the Earth; that point to which the eye of an observer refers the object.

Place, True.—That point in which a heavenly body would appear if viewed from the centre of the Earth.

Plane, (*planus,* even.)—A figure or surface lying evenly between its boundary lines. *Euclid.*

Planet, (πλανάω, *to wander; i. e.* literally, *a wandering star.*)—A celestial body revolving round the Sun or other planet as a centre.

Planets, Exterior or **Superior.**—Those planets whose orbits are beyond or without the orbit of the Earth.

Planets, Inferior.—Otherwise called *interior planets,* which see.

Planets, Interior.—The planets Mercury and Venus are called interior planets because their orbits are within that of the Earth.

Planets, Primary.—Planets which move round the Sun as a centre.

Planets, Secondary.—Planets which revolve round another planet as their centre.

Planets, Telescopic.—See TELESCOPIC PLANETS.

Planetarium.—See ORRERY.

Planetary Nebulæ.—Nebulæ exhibiting discs of uniform brightness, but not resolvable into stars.

Planisphere.—The sphere or globe projected on a plane surface.

Platonic Year.—The period of time determined by the revolution of the equinoxes. It is sometimes called the *great year.*

Pleiades.—A group of stars in the constellation Taurus.

Plumb-line, or **Plummet,** (*plumbum,* lead.)—A cord or string having a piece of lead attached at one extremity. It is used by astronomers for the purpose of adjusting an instrument to the perpendicular.

Poetical Rising and Setting.—See ACHRONICAL, COSMICAL, and HELIACAL, rising and setting of the stars.

Point.—In astronomy, a term applied to certain fixed places in the heavens. Thus, the four grand divisions of the horizon, East, West, North, and South, are called the *cardinal points;* the zenith and nadir are the *vertical points;* the intersection of the equator and ecliptic are called the *equinoctial points;* the Sun's highest ascent above and greatest descent below the equinoctial are called the *solstitial points;* those points in the orbit of a planet which intersect the ecliptic are called the *nodal points.*

Pointers.—This name is given to the stars *Merak* and *Dubhe,* in Ursa Major, because a line drawn through them and extended will designate the *pole star.*

Polar.—Relating to the poles.

Polar Axis of a Telescope.—That axis of an equatorial instrument which is parallel to the axis of the Earth.

Polar Circles.—Two lesser circles of the sphere, distant 23° 28′ from each pole. The northern is called the Arctic, and the southern the Antarctic Circle.

Polar Compression.—The flattening of the Earth's planet at the poles.

Polar Diameter.—That diameter of a sphere which passes through the centre and is terminated both ways by the poles.

Polar Distance.—The angular distance of a celestial body from the pole. Polar distances are always reckoned from the North pole from 0° up to 180°, by which means all ambiguity of expression with respect to the sign is avoided.

Polaris.—Another name for the *pole star.* It is known as α Ursæ Minoris, Alrucabba, and Cynosura.

Pole, Altitude of.—An arc of the meridian intercepted between the pole and the horizon of any place, and is equal to the latitude of the place.

Pole Star, or **Polar Star.**—The bright star in the end of the tail of Ursa Minor, called by the names of *Cynosura, Alrucabba,* &c. It is called the pole star because it is within a very small angular distance from the pole of the sphere. It is also called *Polaris.*

Poles.—The extremities of the axis on which the Earth revolves; the poles of the heavens are those extremities extended to the region of the stars.

Pollux.—A name given to β Geminorum, the second star in the constellation Gemini.

Polymnia.—The thirty-third asteroid. It was discovered by Chacornac, October 28, 1854.

Pomona.—The thirty-second asteroid. It was discovered by Goldschmidt the 20th of October, 1854.

Porrima.—A binary star in the constellation Virgo, marked γ Virginis in the catalogues. This star is also called *Postvarta.*

Position.—Position in the meridian is that adjustment of the transit-instrument whereby the telescope is brought into the plane of the meridian.

Position, Apparent Instrumental, of an Object.—That position of an object indicated by an instrument, whether properly adjusted or not.

Position Micrometer. — See MICROMETER.

Positions of the Sphere.—There are three positions of the sphere: *Right, Parallel,* and *Oblique,* which see under those heads.

Position, True Instrumental, of an Object.—That position indicated by an instrument in perfect adjustment within itself.

Postvarta.—See PORRIMA.

Præsepe.—A group of stars in the constellation Cancer, familiarly called the *Beehive.*

Practical Astronomy.—That branch of astronomy which treats of astronomical instruments and their application.

Praxiteles.—See CELA SCULPTORIA.

Precession of the Equinoxes.—A retrograde motion of the equinoctial points, in consequence of the action of the Sun and Moon upon the protuberant matter at the Earth's equator.

Precession, General, of the Equinoxes.—The combined effect arising from the simultaneous action of all the celestial bodies, estimated in the same direction.

Precession, Luni-solar.—The precession of the equinoxes caused by the united attraction of the Sun and Moon only.

Pressure.—By pressure is meant a force opposed by another force, so that no motion takes place.

Primary Planets.—Those planets which revolve round the Sun as a centre, in contradistinction to the secondary planets, or satellites.

Prime Meridian.—That meridian from which the longitudes of places begin to be reckoned. Almost every nation has its own prime meridian. Longitude in the United States is reckoned from the meridian of Washington, and the meridian of Greenwich is the prime meridian for England.

Prime of the Moon.—The New Moon when she is first visible after the change.

Prime Vertical.—That vertical circle or azimuth which is perpendicular to the meridian, and passes through the east and west points of the horizon.

Priming of the Tides.—See TIDES.

Primum Mobile.—A term in the Ptolemaic Astronomy signifying the *First mover.* It is the highest sphere in the heavens, containing all the other spheres within it, and giving motion to them; from whence its name. It was supposed to turn round in twenty-four hours.

Prism.—A piece of glass of any length having parallel sides and triangular ends, which separates the rays of light passing through it, in consequence of the different degrees of refrangibility that take place in different parts of the same ray.

Prismatic Colors.—The colors manifested by the decomposition of a ray of light in passing through a prism.

Problem.—A proposition requiring a solution.

Procyon.—The principal star in Canis Minor, generally known as α Canis Minoris.

Projectile.—Any body which, being put into a violent motion by an external force impressed upon it, is dismissed from the agent and left to pursue its course.

Projection of the Sphere.—The representation of the several points or places of the surface of the sphere, and of the

circles described upon it, upon a supposed transparent plane placed between the eye and the sphere. The projection of the sphere is divided into *orthographic, stereographic,* and *gnomonical.*

Prolate Spheroid.—See SPHEROID.

Proper Motion.—That motion which some stars are found to possess, independent of the apparent change of place owing to the precession of the equinoxes, and which may be due either to the actual motion of those stars, or to the motion of our solar system. It is, no doubt, in most instances, the combined result of both motions.

Proserpine.—An asteroid discovered by Luther, May 5, 1853. It is the twenty-sixth in the order of discovery.

Prosthaphæresis.—Another name for the equation of the centre or of the orbit. It is the difference between the true and mean motion or true and mean place of a planet.

Psyche.—An asteroid discovered March 16, 1852, by Gasparis. It is the sixteenth in the order of discovery.

Ptolemaic System.—The arrangement of the heavenly bodies according to the theory of its founder Ptolemy.

Puppi.—A name given to the stern of the ship in the constellation Argo.

Pythagorean System.—The theory of the solar system, which has since been called the Copernican; but which differs but little from that of Pythagoras.

Pyxis Nautica.—A southern constellation, the middle of which is R. A. 8*h.* 50*m.*, Dec. 30° S.

Quadrangle.—A figure having four angles.

Quadrant.—In geometry, a quadrant is either the fourth part of a circle or the fourth part of its circumference, the arc of which contains 90°. It also denotes a mathematical instrument for taking the altitudes of celestial objects, and also for taking angles in surveying heights, distances, &c. The quadrant is of great use in astronomy and navigation. It was invented by Thomas Godfrey, an American mathematician, was taken to England, and has since been claimed as the invention of Hadley, an English contemporary.

Quadrant of Altitude.—An appendix to the artificial globe, consisting of a thin slip of brass, the length of a quarter of one of the great circles of the globe, and graduated. Its use is to serve as a scale in measuring altitudes, amplitudes, azimuths, &c.

Quadrature.—That aspect of the Moon when she is 90° distant from the Sun. The quadratures or quarters of the Moon are those two points of the Moon's orbit midway between the points of conjunction and opposition.

Quadrilateral.—A figure comprehended by four right lines.

Quarters of the Heavens.—The four cardinal points.

Quarters of the Moon.—Certain periods in the Moon's age, known as the first quarter, and third or last quarter, which occur when she is 90° from the Sun east, and the same distance west of that luminary. See QUADRATURE.

Quartile. An aspect of the planets when they are three signs or 90° from each other, that distance being one-fourth of the whole circumference. It is known by the character □ in astronomical works.

Quintile.—An aspect of the planets when they are 72°, or the fifth part of the zodiac, distant from each other. This term is now not much used.

Radiant.—That self-luminous body which emits rays of light; or an opaque body which reflects them.

Radius, (*radius*, a ray or spoke.)—Half the diameter of a circle, or the distance from the centre to the circumference.

Radius Vector.—An imaginary line joining the centre of a planet or comet and that of the Sun, or uniting the centre of a planet and that of its satellite.

Rare.—Thin, not dense.

Rasaben.—A name given to the star γ Draconis in the Alphonsine Tables, but generally known by the name of *Etamin.* It passes very near the zenith of Greenwich, and is the star by which Bradley

made the important discovery of the aberration of light.

Ras-al-asad, Australis.—A small star in the constellation Leo; also known as ε Leonis.

Ras-al-asad, Borealis.—A star in the constellation Leo, marked in the catalogues μ Leonis. It is also called *Rasalas.*

Rasalgeti.—A bright star in the constellation Hercules; also called α Herculis.

Ras Alhague.—A star in the constellation Ophiuchus; also called α Ophiuchi.

Rate of the Clock.—The change of its error in the space of twenty-four hours.

Ratio.—The relation of two magnitudes of the same kind in respect of quantity.

Ray.—A beam or line of light propagated from a radiant point. It is also used for *radius.*

Rays, Converging.—Those rays which constantly approach nearer to each other until they unite in one point, called the focus.

Rays, Direct.—Rays of light which are in a straight line between the radiant point and the eye.

Rays, Diverging.—Those rays which proceed from a point and continually recede from each other.

Rays, Parallel.—Those rays which continue equally distant from each other throughout their whole course. Rays proceeding from the heavenly bodies are considered parallel.

Rays, Reflected.—Rays of light which strike the surface of a body and are thrown off again.

Rays, Refracted.—Rays of light which are bent out of their straight course.

Reading Microscope. A species of compound microscope, consisting of three lenses, one of which is the object lens, and the other two constitute the eye-piece. This instrument is used for reading the graduated arc of a mural circle, &c.

Real Motion.—The motion of the planets as seen from the Sun.

Recession of the Equinoxes.—See Precession.

Rectangle.—A right-angled parallelogram, or a right-angled quadrilateral figure; any solid whose angles are all right angles.

Reduction.—The correction of an observation, either for the errors of the clock, or for those caused by the adjustments of the instruments.

Reflection.—That motion in the rays of light, whereby, after a near approach to the surfaces of solid bodies, they recede, or are thrown back.

Reflecting Telescope.—Those telescopes which represent the images of distant objects by reflection. This kind of telescope is said to have been invented by James Gregory in 1663, the idea of which he received from Mersenne, who suggested it to Descartes as early as the year 1643.

Refraction.—The bending or breaking of a ray of light in passing out of one medium into another of a different density. It is a bending of the rays of light in passing through our atmosphere, by which the apparent altitudes of the heavenly bodies are increased.

Refracting Telescope.—A telescope consisting of an object-glass inserted in one end of a tube, and an eye-lens or magnifying glass at the other end.

Refrangibility. The disposition in rays of light to be refracted, or turned out of a direct line in passing out of one transparent body or medium into another.

Regulus.—A brilliant star of the first magnitude in the constellation Leo; also known as α Leonis or *Cor Leonis.* The name of *Basiliscus* was given to this star by Ptolemy.

Resisting Medium.—See Medium.

Resolvable Nebulæ.—Such Nebulæ as excite suspicion that they consist of stars, and which an increase of optical power in the telescope may be expected to resolve.

Resolution of Forces.—The resolving or dividing any force or motion into several others, in other directions, but which, taken together, shall have the same effect as the single one.

Rest.—The continuance of a body in the same place. It is either *absolute* or

relative. *Absolute rest* is the continuance of a body in the same part of absolute and immovable space. *Relative rest* is its continuance in the same part of relative space; as, in a ship under sail, the continuance of a body in the same part of the ship is only relative rest. In reality there is no such thing as absolute rest, for all the heavenly bodies are suspected of motion.

Resultant Wave.—See WAVE.

Resulting Force.—The joint effects of a number of forces united into one.

Reticula or **Reticle.**—An instrument for measuring the quantity of eclipses with great nicety by means of silken threads attached to it. The most simple kind of micrometer. *La Lande.*

Reticulus Rhomboidalus.—A southern constellation, the middle of which is R. A. 3*h.* 44*m.*, Dec. 62° S.

Retrocession of the Equinoxes.—See PRECESSION.

Retrogradation.—An apparent motion of the planets, by which they seem to go backwards in the ecliptic, and to move contrary to the order of the signs.

Retrogradation of the Moon's Nodes.—A motion of the line of the nodes of the Moon's orbit, by which it continually shifts its situation from east to west, contrary to the order of the signs, completing its retrograde revolution in the period of nineteen years.

Retrograde Motion.—See MOTION.

Revolution.—The motion of any body in a curved line until it returns to the same point again. The motion of a planet round the Sun, or of a satellite around its primary.

Revolution, Annual.—The yearly motion of the Earth round the Sun.

Revolution, Anomalistic.—The same as Anomalistic Year, which see.

Revolution, Diurnal.—The motion of a body round its own axis.

Revolution, Nodical.—The time required for the node of a planet or satellite to occupy successively every point in its orbit and return again to the same place.

Revolution, Time of.—The time a heavenly body requires to perform its journey round its centre of motion. It is synonymous with *periodic time.*

Revolution, Sidereal.—The consecutive returns of a planet to the same star.

Revolution, Tropical.—The consecutive returns of a planet to the same tropic or equinox.

Rhea.—The fifth satellite of Saturn; it was discovered by Dominic Cassini, December 23, 1672.

Rigel.—A star of the first magnitude in the constellation Orion; also known as β Orionis.

Right Angle.—A right angle is formed by a perpendicular line falling on a horizontal one. A right angle contains 90°.

Right-Angled Triangle.—A triangle having one right angle.

Right Ascension.—The distance of any heavenly body measured on the equinoctial from the first point of Aries.

Right Sphere.—That position of the sphere by which its poles are in the horizon.

Ring.—A thin, broad circle encompassing the planet Saturn without touching it.

Ring Micrometer.—A small circle of brass so fixed in the eye-piece of a telescope as to appear to the observer suspended in the centre of the field of view. The time of the appearance and disappearance of an object on the outer and inner edges of the ring are accurately noted, by which means the difference of right ascension and declination of two or more stars is ascertained.

Rising.—The appearance of the Sun, star, or planet, above the horizon, which before was concealed beneath it. There are three kinds of rising, termed poetical rising: viz., the *achronical, cosmical,* and *heliacal.*

Robur Caroli.—A southern constellation, the middle of which is R. A. 10*h.* 8*m.*, Dec. 60° S.

Rotanev.—Another name for β Delphini, a star in the constellation Delphinus.

Rotation.—The motion of a body, or system of bodies, about a line or point.

Rotary.—Revolving on an axis.

Ruchbah.—A star in the constellation Cassiopeia, known also as δ Cassiopeiæ.

Ruchbah-ur-Ramih.—Another name for α Sagittarii, a star in the constellation Sagittarius.

Rudolphine Tables.—A set of mathematical tables, published by Kepler in 1628, and called after the emperor Rudolph.

Rukbat.—A double star in the constellation Cygnus; also known as ω^3 Cygni.

Sabik.—Another name for a star in the constellation Ophiuchus; known also as η Ophiuchi.

Sadachbia.—Another name for γ Aquarii, a star in the constellation Aquarius.

Sa'd-al-Melik.—A star of the third magnitude in the constellation Aquarius; also called α Aquarii.

Sa'd-as-Suud.—See Kalpeny.

Sadr.—Another name for γ Cygni, a star in the constellation Cygnus.

Sagitta.—One of the northern constellations, the middle of which is R. A. 19*h.* 48*m.*, Dec. 18° N.

Sagittarius.—One of the zodiacal constellations, the middle of which is R. A. 19*h.* 0*m.*, Dec. 30° 0′ S.

Saiph.—A star in the constellation Orion; also called χ Orionis.

Saros.—The period of 6585·78 days, in which eclipses occur again very nearly in the same order within the same period. It was called Saros by the Chaldean and Egyptian astronomers. It is also known as the Period of Eclipses.

Satellite.—Secondary planet or Moon revolving around another planet as its centre, as the Moon revolves round the Earth.

Saturn.—The next planet beyond Jupiter. By the Hebrews he was called *Shebtai*, rest, and by the Greeks χρονος, time; because he is so long a time in performing his journey round the Sun.

Saturnicentric.—As seen from, or having relation to, the centre of the planet Saturn.

Scale.—The degrees and minutes of an arc of a circle, or of any right line drawn or engraved upon a ruler.

Scheat.—One of the stars in the constellation Pegasus; also called β Pegasi, though the Arabs called it Menkib. It is the north-western star in the *Square of Pegasus.* The name of Scheat is also given to δ Aquarii, a star in the constellation Aquarius.

Schedir.—A star of the third magnitude; also called α Cassiopeiæ.

Schemali.—A star in the extremity of the tail of Cetus; also termed ι Ceti.

Scintillation.—The twinkling or tremulous motion of the light of the fixed stars, supposed to be due to the *interference of light.*

Scorpio.—One of the zodiacal constellations, the middle of which is R. A. 16*h.* 19*m.*, Dec. 26° N.

Scutum Sobieski.—One of the northern constellations, the middle of which is R. A. 18*h.* 32*m.*, Dec. 10° S.

Sea Astrolabe.—An instrument used for taking altitudes at sea; as the altitude of the pole, the Sun, or the stars.

Seasons.—The four portions or quarters of the year, distinguished by the names of Spring, Summer, Autumn, and Winter.

Secant.—A line cutting a circle lying partly within and partly without it.

Second.—In *time*, it is the 60th part of a minute, the 3600th part of an hour, and the 86,400th part of a day. In *angular measurement*, it is equal to the 60th part of a minute, the 3600th part of a degree, and the 1,296,000th part of the whole circumference.

Secondary Planet.—See Satellite.

Secular Acceleration.—A slow change in the eccentricity of the Earth's orbit, which has sensibly diminished the length of the Moon's revolution since the time of the earliest observations. The eccentricity of the Earth's orbit is decreasing at the rate of about forty miles annually; and, were it to decrease at that rate steadily, it would require 39,861 years to bring it to a circle.

Sector.—That portion of a circle included between two radii and their included arc.

Sector, Astronomical.—An instrument for finding the difference in right ascension and declination between two objects whose distance is too great to be measured by means of a micrometer in a fixed telescope.

Sector of a Sphere.—The conic solid whose vertex ends in the centre and its base in the segment of the same sphere.

Secular Equations, or **Century Equations.**—Corrections required to compensate such inequalities in the celestial motions as occur in the course of a century, or one hundred years.

Secular Inequalities.—Variations in the motions of the heavenly bodies, requiring an indefinite period for their accomplishment, sometimes amounting to many centuries.

Segment.—A part cut off a figure by a line or plane. The part remaining after the segment is cut off is called a frustum.

Selenocentric.—As seen from, or having relation to, the centre of the Moon.

Selenography, (σεληνη, *the Moon,* and γραφω, *to describe.*)—The description and representation of the Moon, with all the parts and appearances of her disc or face; as geography is of the surface of the Earth.

Semicircle.—Half a circle, or a segment cut off by a diameter.

Semidiameter. — Half the diameter of a sphere; the radius.

Semi-Diurnal Arc.—One half the arc described by a heavenly body between its rising and setting.

Semi-Sextile.—An aspect of two planets when they are distant from each other 30° or one sign.

Sensible Horizon.—See HORIZON.

September, (*septem,* seven.)—In the Roman year, this was the seventh month; but is the ninth according to our reckoning.

Sequences.—A term employed by Sir J. Herschel in some of his tables, to signify the gradual diminution of the apparent magnitude of the individuals of certain series of stars when compared with each other.

Serpens.—One of the northern constellations, the middle of which is in R. A. 17*h.* 0*m.*, Dec. 3° 0′ N.

Serpha.—See DENEBOLA.

Serpentarius.—Another name for *Ophiuchus,* which see.

Sesquiplicate.—Having the ratio of two and a half to one.

Setting.—The descent of the Sun, star, or planet, below the horizon.

Seven Stars.—See PLEIADES.

Sexagesimal.—The division of the circle by *sixties.*—Thus, the circumference is divided into 360 equal parts called degrees, and each degree into 60 equal parts called minutes, and each minute into 60 equal parts called seconds.

Sextans.—A southern constellation, the middle of which is R. A. 10*h.* 0*m.*, Dec. 0°.

Sextant.—The sixth part of a circle; an astronomical instrument.

Sextile.—The aspect or position of two planets when they are distant the sixth part of the circle or 60°; it is marked thus ✱.

Sheliak.—A star in the constellation Lyra; also known as β Lyræ.

Sheratan.—A star in the constellation Aries, called β Arietis.

Shooting Stars.—See METEOR.

Sidereal, (*sidus,* a star.)—Relating to the stars.

Sidereal Astronomy.—That branch of astronomy which treats of the stars.

Sidereal Clock.—A clock which marks sidereal time; that is, which goes at such a rate as to show 0*h.* 0*m.* 0*s.* when the equinox comes to the meridian. This is an indispensable piece of furniture in every observatory.

Sidereal Day.—The interval of time between two consecutive passages of the meridian over the mean equinox.

Sidereal Day, Apparent. The interval of time between two consecutive passages of the meridian over the apparent equinox.

Sidereal Time.—See TIME.

Sidereal Year.—See YEAR.

Sidus, or **Georgium Sidus.**—The name given to Uranus by its discoverer, Dr. Wm. Herschel.

Sign.—A twelfth part of the ecliptic or zodiac, containing 30°.

Signs.—See CHARACTERS.

Sine.—The perpendicular drawn from the extremity of an arc to the diameter of a circle.

Sirius.—The brightest star in the firmament; also called α Canis Majoris. The Egyptians are supposed to have given the name of Sirius to this star from *Siris,* which was one of the names of the river Nile; for that stream began to swell at that time of year when Sirius rose with the Sun. Sirius is also known by the name of the *Dog Star;* and it is also called *Canicula.*

Situla.—A name given to a star in the constellation Aquarius, called also κ Aquarii. This star was called by the Arabs Al-Delio.

Solar, (*Sol,* the Sun.)—Relating to the Sun.

Solar Apex.—The point in space toward which the Sun is moving.

Solar Day.—See Day.

Solar Spectrum.—The oblong image formed by the prism, and divided into seven colored bands or spaces.

Solar System.—The Sun and the bodies which revolve around him.

Solar Time, Apparent.—Time measured by the hour angle of the Sun.

Solar Year.—See Year, Tropical.

Solstices, (*Sol,* the Sun, and *sisto,* to stand.) —The points in which the Sun is farthest from the equator; at which time he appears to *stand still* for a few days.

Solstitial Colure.—The great circle which passes through the solstitial points.

Solstitial Points.—The points in the ecliptic which designate the Sun's place at the time of the solstices; they are the first points of Cancer and Capricorn, and are 90° from the equinoctial points.

South.—One of the four cardinal points, being that directly opposite to the north. A star, planet, or the Moon, is said to be *south* when it crosses the meridian south of the observer.

Southing.—The passing of any celestial body over the meridian. It is particularly used in regard to the Moon.

Southern Constellations.—See Constellations.

Southern Signs.—Those six signs of the zodiac situated south of the equator: viz., Libra, Scorpio, Sagittarius, Capricornus, Aquarius, and Pisces.

Space.—Infinite extension in all directions.

Spectrum, (*specto,* to behold.)—The image formed on any white surface by a ray of solar light passing through a small hole into a dark chamber, when refracted by a triangular glass prism. The ray is divided into seven bands exhibiting the seven colors observable in the rainbow; the image is called the *spectrum,* and, because it is produced by means of a prism, it is also termed the *prismatic spectrum.* The colors forming the spectrum are the *prismatic colors.*

Speculum, (*specio,* to view.)—A mirror; a metallic reflector used in reflecting telescopes, instead of the object-glass used in refracting telscopes; any polished body impervious to the rays of light.

Sphere.—A solid body contained under one single uniform surface, every point of which is equally distant from a point in the middle called its centre.

Sphere, Armillary, (*armilla,* a bracelet or ring for the arm.)—An astronomical instrument representing the several circles of the sphere. They are made of rings of brass, serving to illustrate the position of the different circles, and to solve the various problems relating to them.

Sphere, Oblique.—That position of the Earth when the rational horizon cuts the equator obliquely. All the inhabitants of the Earth, except those who live at the poles or at the equator, have this position of the sphere.

Sphere, Parallel.—That position in which the rational horizon coincides with the equator, the zenith and nadir being the poles. The inhabitants, if any, who have this position of the sphere are those who live at the poles.

Sphere, Right.—That which cuts the equator at right angles, or that which has the poles in the horizon and the equinoctial in the zenith. The inhabitants at the equator have this position of the sphere.

Spheroid.—A solid body approaching to the figure of a sphere, but having one of its diameters longer than the other.

Spheroid, Oblate.—A figure formed by the rotation of an ellipse about the shorter axis.

Spheroid, Prolate.—A figure produced by the revolution of a semi-ellipse about its longer diameter.

Spica.—Another name for the star α Virginis, belonging to the constellation Virgo. It was called *As-Simak* by the Arabs, and its Nubian name was *Eleazelet*.

Spiral Nebulæ.—See NEBULÆ.

Sporades, (from *σπειρω, to scatter.*)—A name given by astronomers formerly to such stars as were not included in any constellation; they are now called *unformed* stars.

Spots.—Certain portions of the Sun's or Moon's disc, observed to be either brighter or darker than the rest. See FACULÆ and MACULÆ.

Spring Tides.—The high tides about the times of New and Full Moon.

Star.—A general name for most of the heavenly bodies.

Star-Dust.—A name applied to patches of extremely minute stars, as seen through the telescope.

Stars, Fixed.—Those celestial bodies which retain the same, or *nearly* the same, positions with regard to each other.

Stars, Temporary.—Those stars which appear suddenly, and vanish after being visible a short time.

Stars, Variable.—Those stars which exhibit periodical fluctuations of brilliancy.

Stationary.—The state of a planet when, to an observer on the Earth, it appears for some time to stand still, because it is moving in a line with the eye.

Stellar.—Relating to the stars.

Style.—A particular manner of computing time, as *Old Style* and *New Style.*

Style, Old.—The Julian manner of reckoning, as instituted by Julius Cæsar.

Style, New.—the Gregorian manner of computing, as instituted by Pope Gregory XIII. in the year 1582.

Sub-Polar.—Below the pole; on the lower meridian.

Succession of the Signs.—That order in which they are commonly reckoned, as Aries, Taurus, Gemini, Cancer, &c.

Sulaphat.—A bright star in the constellation Lyra; also known as γ Lyræ.

Sun.—The great centre of the solar system.

Sun's Horizontal Parallax.—The greatest angle under which the equatorial semidiameter of the Earth would appear at the Sun's centre.

Sun's Mean Longitude.—The arc of the ecliptic from the vernal equinox to the place the Sun would appear to occupy, had his motion been uniform and equal.

Sunday Letter.—See DOMINICAL LETTER.

Superior Conjunction.—See CONJUNCTION.

Superior Planets.—The same as the exterior planets.

Superior Meridian.—That half of the meridian above the horizon.

Svalocin.—A star in the constellation Delphinus, called also α Delphini.

Sweep.—A word applied to an examination of the sky by "sweeping" the telescope over a long extent of the heavens, and thus observing a band whose breadth is the width of the field of view embraced in the instrument, and whose length is the length of the arc of the heavens surveyed. This method of observing is accomplished with great facility by clamping the telescope, and allowing the stars to move through the field. In this case the length of the sweep is measured by the length of time the eye is at the instrument; and, by changing the altitude of the telescope after each sweep, so that the lower edge of the field of one observation shall be the upper edge of the other, the whole sky may be examined. *Gould.*

Symbol, Astronomical.—See CHARACTERS.

Synodic Revolution.—The time between two conjunctions or two oppositions of the Moon or a planet.

Synodical Month.—See LUNATION.

System.—An hypothesis or a supposition of a certain order and arrangement of the several parts of the universe, by which astronomers explain all the phenomena or appearances of the heavenly bodies; a number of bodies revolving round a common centre. The principal systems which have been embraced are

four; namely, the *Ptolemaic*, the *Egyptian*, the *Tychonic*, and the *Copernican.*

System, Copernican. — That system of the universe as taught by the astronomers of the present day. It was first promulgated by Pythagoras 2300 years ago, and was again revived in the fifteenth century by Nicholaus Copernicus.

System, Egyptian.—That system of the universe taught by the Egyptian astronomers, in which the Earth is the centre, and the Sun and Moon revolve around it. The planets and Mercury and Venus revolve round the Sun, and the exterior planets in orbits far distant.

System, Ptolemaic.—That system of the universe taught by Ptolemy. It consisted of the Earth in the centre, and the Moon, Mercury, Venus, the Sun, Mars, Jupiter, and Saturn, revolving round it in the above-named order.

System, Tychonic.—That system of astronomy taught by Tycho Brahé. It consisted of the Earth in the centre, with the Moon revolving round it, and the Sun as the centre of the orbits of the other planets. The Sun, according to this system, was supposed to revolve round the Earth.

Syzigies, (from συζευξις, conjunction.)—Those points in the Moon's orbit where she is new and full.

Tables.—Astronomical tables are the computations of the motions, places, and other phenomena of the heavenly bodies.

Tables, Alphonsine. — A set of astronomical tables published about the year 1250, under the patronage of Alphonso X., King of Castile and Leon.

Tables, Danish.—Tables of the motions of the Sun, Moon, and planets, by Longomontanus, from the observations of Tycho Brahé.

Tables, Ludovician.—Tables composed by De la Hire, in 1702. The observations were entirely his own, without the assistance of any hypothesis; which, before the invention of the micrometer and pendulum clock, was deemed impossible.

Tables, Prutenic. — Tables compiled by Erasmus Reinhold from the observations and calculations of Copernicus.

Tables, Rudolphine.—Astronomical tables made by Kepler from the observations of Tycho and his own.

Tabulæ Toledanæ.—A set of astronomical tables made by Arzachel, an Arabian astronomer, in 1020.

Tail of a Comet.—The train of luminous light which shoots out from a comet.

Talita.—A star in Ursa Major, called ι Ursæ Majoris.

Tangent, (*tango*, to touch.)—A line that touches a curve; that is, which meets it in a point without cutting it, though it be produced both ways.

Tangent Screw.—A screw which works tangentially, imparting a slight motion to an astronomical instrument.

Tangential Force.—A force exerted in the direction of a tangent.

Tarandus.—A northern constellation, the middle of which is situated R. A. 2*h.* 32*m.*, Dec. 80° N.

Tarazed.—A star in the constellation Aquila; also known as γ Aquilæ.

Taurus.—One of the twelve signs of the zodiac, and the second in order, the middle of which is R. A. 4*h.* 20*m.*, Dec. 16° N.

Taurus Poniatowski.—A northern constellation, situated in R. A. 18*h.* 20*m.*, Dec. 7° N.

Taygeta.—A name given to one of the Pleiades.

Tegmine.—A triple star in the constellation Cancer; called also ζ Cancri.

Telescope, (τυλε, *far; in the distance;* and σκοπεω, *to observe.*)—An optical instrument which serves for discovering and viewing distant objects, either directly by glasses, or by reflection by means of speculæ or mirrors.

Telescope, Achromatic, (*a, deprived of,* and χρομα, *color.*)—A telescope invented by Mr. Dollond, and so contrived as to remedy the aberration arising from colors.

Telescope, Meridian, or **Transit Instrument.**—See TRANSIT INSTRUMENT.

Telescopic Comets.—Those comets which are invisible without the aid of a telescope.

Telescopic Planets.—The asteroids, or, as they are sometimes called, the Planetoids, are also known as the *telescopic planets.* The planet Neptune cannot be seen without the aid of a telescope.

Telescopic Stars.—Those stars which are invisible without the aid of a telescope.

Telescopium.—A southern constellation, the middle of which is R. A. 18*h.* 20*m.*, Dec. 52° S.

Temperate Zone.—That zone or space situated between the tropics and polar circles.

Temporary Stars.—Stars which have suddenly appeared, shining with great brilliancy, and after a time disappear entirely.

Terminator.—That line which separates the illuminated from the unilluminated portion of the Moon's disc.

Terrestrial, (*terra,* the Earth.)—Appertaining to the Earth.

Tethys.—The third satellite of Saturn. It was discovered by Dominic Cassini in March, 1684.

Thalia.—An asteroid discovered by Hind, December 15, 1852. It is the twenty-third in the order of discovery.

Thebit.—An inequality on the lunar surface is known by this name.

Theemim.—Another name for υ Eridani, a star in the constellation Eridanus.

Themis.—An asteroid discovered by Gasparis, August 5, 1853. It is the twenty-fourth in the order of discovery.

Thermometer, (φερμος, *heat,* and μετρον, *a measure.*)—An instrument for measuring the temperature of the air, water, &c.

Thermoscope.—A species of thermometer.

Thetis.—An asteroid discovered by Luther, April 17, 1852. It is the seventeenth in the order of discovery.

Thuban.—A star in the constellation Draco, known also as α Draconis. About 4600 years ago it was the north pole star.

Tide, (from the Saxon *tid,* which signifies time or season.)—Two periodical motions of the waters of the sea, produced by the action of the Sun and Moon. They are called the *flux* and *reflux,* or *ebb* and *flood.*

Tide-Day.—The interval between the occurrences of two consecutive maxima of the *resultant wave* at the same place. The tide-day varies as the component waves approach to, or recede from, one another.

Tide-Gauge.—An instrument employed for discovering the height of the tides.

Tides, Apogean.—See APOGEAN.

Tides, Atmospheric.—Atmospheric tides are certain periodical changes in the atmosphere, similar, in some respects, to those which take place in the ocean, and produced, in a measure, by the same causes.

Tides, Derivative Ebb.—Low water succeeding the apex of the tide-wave after it has passed onward and the water flows out into the sea.

Tides, Derivative Flood.—The approach of the tide-wave along shallow shores and beds of estuaries, intercepting the free transmission of the tide and causing it to be heaped up in the ocean, produces *derivative flood-tides.*

Tides, Lagging of.—The variation in the length of the tide-day, indicating a retardation of the recurrence of high water at any given place.

Tides, Perigean.—See PERIGEAN.

Tides, Priming of.—The variation in the length of the tide-day, owing to the acceleration of the recurrence of high water at any given place.

Tide-Tables.—Tables exhibiting the time of high water at sundry places.

Tide-Wave, Derivative.—The swell in rivers and channels produced by the primitive tide-wave, or general swell of the ocean.

Tide-Wave, Primitive.—The general swell of the ocean.

Time.—Duration marked by the motion of the heavenly bodies, particularly that of the Earth on its axis, being the most regular occurrence which comes under the notice of man. See MEAN TIME, and DAY, MEAN SOLAR.

Time, Apparent.—Time denoted by an observation of the Sun; that is, by the arrival of the real Sun at the meridian, and is the time indicated by dials.

Time, Equinoctial.—The mean longitude of the Sun converted into time at the rate of 360° to the tropical year. A method of reckoning time for astronomical purposes, called equinoctial time, was suggested by Sir John Herschel. Its object is to avoid the necessity of mentioning the place to which the time of an observation refers, for any particular hour mean time at Greenwich is not the same hour at that moment on any other meridian, but differs therefrom by the longitude of the place. Sir John Herschel proposed the moment of the vernal equinox as a starting-point for the reckoning of time which would be common to all nations. *Hind.*

Time, Mean.—Time denoted by the mean Sun; that is, time reckoned by the arrival of an imaginary sun at the meridian, or of one which is supposed to move uniformly in the equinoctial at the rate of 59′ 8″·33 every day, which is the time given by clocks and watches in common life.

Time, Sidereal.—The time shown by a clock regulated by the fixed stars.

Titan.—The sixth satellite of Saturn. It was discovered by Huyghens, March 25, 1655.

Titania.—A name given by Sir John Herschel to the fourth satellite of Uranus.

Torrid Zone, (*torreo,* to roast.)—That zone or space situated between the tropics, over some part of which the sun is always vertical.

Total Eclipse.—The entire obscuration of a celestial object by a body or shadow of another body.

Toucan.—A southern constellation, the middle of which is in R. A. 23*h.* 55*m.*, Dec. 66° S.

Trajectory.—A curvilinear path described by a body, as the orbit of a comet.

Transit, (*trans,* beyond, and *eo,* to go.)—The passage of any planet just before or over the Sun, another planet, or a star, or the passing of a heavenly body over the meridian or across the field of a telescope.

Transit Circle.—An instrument so constructed that the right ascension and declination of a heavenly body may be determined at its transit over the meridian.

Transit Instrument.—A telescope fixed at right angles to a horizontal axis; this axis being so supported that the line of collimation may move in the plane of the meridian; a telescope so mounted as to observe the passage of a heavenly body across the meridian.

Transits of Satellites.—The passage of the shadows of Jupiter's satellites across his disc, which to the inhabitants of Jupiter produce eclipses of the Sun. Sometimes these satellites have been seen to transit his disc like beads of light.

Transit, Upper.—The passage of a star across the upper or superior meridian of any place; that is, the passage across the great circle passing through the zenith of the place and the north and south points of the horizon.

Transit, Lower.—The passage of a heavenly body over the lower or inferior meridian of the place; that is, over the meridian differing 180° from the longitude of the place.

Transparent, (*trans,* through, and *pareo,* to appear.)—That condition of a body which permits light to pass through it freely.

Transverse Axis.—See Axis.

Triangle, (*τρεις, three.*)—A figure bounded by three straight lines, and which consequently has three angles, from which the figure takes its name.

Triangulum.—A northern constellation, the middle of which is in R. A. 1*h.* 48*m.*, Dec. 32° N.

Triangulum Australis.—A southern constellation, R. A. 16*h.* 0*m.*, Dec. 65° S.

Triangulum Minus.—A northern constellation, the middle of which is situated in R. A. 1*h.* 28*m.*, Dec. 27° N.

Trine.—The aspect or situation of one planet with respect to another, when they are distant 120°, or the third part of the circle.

Triones.—The assemblage of seven stars in the constellation Ursa Major, popularly called *Charles's Wain.*

Triple Stars.—Three stars forming a system and revolving about one common centre of gravity.

Triquetrum.—An ancient astronomical instrument, supposed to have been invented by Ptolemy for determining the altitudes and amplitudes of the heavenly bodies.

Tropical Revolution of the Moon.—The passage of the Moon from one longitude to the same longitude again.

Tychonic or **Tychonean System.**—That system of the universe as taught by Tycho Brahé.

Tropical Year.—See YEAR.

Tropics, (*τρεπω, to turn;* because when the Sun arrives at these points he seems to turn or bend his course.)—Two circles situated 23° 28′ on each side of the equator, and between which the Sun is always vertical.

True Anomaly.—See ANOMALY.

True Motion.—See MOTION.

True Place of a Star or Planet.—A point in the heavens shown by a right line drawn from the centre of the Earth through the centre of the star or planet.

Tureis.—A star in the constellation Argo Navis, situated near the tropic of Capricorn, called ι Argo Navis.

Twilight.—The faint light seen before sunrise and after sunset; the crepusculum.

Tycho.—A lunar mountain.

Ultra Zodiacal Planets.—A term frequently applied to the asteroids; those planets whose orbits are not within the limits of the zodiac.

Umbra.—A shadow.

Umbriel.—A name given by Sir John Herschel to the second satellite of Uranus.

Unformed Stars.—See SPORADES.

Unicorn.—See MONOCEROS.

Universe, (*unum,* one, and *versum,* turning.)—A name applied by the ancients to the whole of the heavens and Earth.

Unuk-al-Hay.—Another name for the principal star in the constellation Serpens, known also as α Serpentis.

Urania.—The thirtieth asteroid. It was discovered by Hind, July 22, 1854.

Uraniburg.—The name of a celebrated observatory, in which Tycho Brahé composed his catalogue of stars. Lat. 55° 54′ N., lon. 12° 47′ E. from Greenwich.

Uranography, (*ουρανος, the heavens,* and *γραφω, to describe.*)—A description of the heavens and the heavenly bodies.

Uranometry, (*ουρανος, the heavens,* and *μετρον, a measure.*)—The measurement of the heavens.

Uranus.—One of the planets of the solar system, situated next beyond the orbit of Saturn. It was discovered by Sir W. Herschel, March 13, 1781, and by him called Georgium Sidus.

Urkab-ur-Ramih.—A name given by the Arabians to the star β Sagittarii, in the constellation Sagittarius.

Ursa Major.—A northern constellation, the middle of which is R. A. 10*h.* 30*m.*, Dec. 60° 0′ N.

Ursa Minor.—It is also called Arctos Minor; one of the northern constellations, the middle of which is R. A. 15*h.* 30*m.*, Dec. 75° N.

Variable Stars.—Stars which exhibit periodic changes of brilliancy.

Variation, Annual.—The difference in the right ascension or declination of a star produced by the combined effect of the precession of the equinoxes and proper motion of the star.

Variation of the Moon.—The third inequality observed in the Moon's motion, by which, when out of her quadratures, her true place differs from her place twice equated.

Vector.—See RADIUS VECTOR.

Vega.—A bright star of the first magnitude in the constellation Lyra; also called α Lyræ, or Wega.

Venus.—One of the interior planets, and second in order from the Sun.

Velis.—A name given to the sails of the ship in the constellation Argo.

Vernier.—A contrivance for measuring intervals between the divisions of graduated scales or circular instruments. It was invented by Peter Vernier.

Vertex.—The zenith; the top of any thing ending in a point.

Vertical, (*verto,* to turn.)—A position at right angles to the plane of the horizon.

Vertical Circle.—A great circle of the sphere, passing through the zenith and nadir.

Vertical Diameter of the Sun or Moon.—The difference of the zenith distances of the north and south limbs, corrected for refraction and parallax.

Vertical Points.—The zenith and nadir.

Vertical, Prime.—See PRIME VERTICAL.

Vertical of the Sun.—The vertical circle which passes through the centre of the Sun at any moment of time.

Vesta.—One of the asteroids discovered by Dr. Olbers, March 29, 1807. It is the fourth in the order of discovery.

Via Lactea.—See GALAXY.

Via Solis.—The ecliptic; the Sun's path.

Victoria.—The twelfth asteroid, sometimes called *Clio.*

Vildiur.—A star in the constellation Ursa Minor; also known as δ Ursæ Minoris.

Vindemiatrix.—A star in the constellation Virgo, marked ε Virginis in the catalogues.

Virgo.—One of the zodiacal constellations, the middle of which is R. A. 13*h.* 14*m.*, Dec. 5° N.

Virgula.—An instrument used by Huyghens to measure the discs of the Sun, Moon, and planets. It consisted of a tapering piece of metal interposed in the common focus of the eye-lens and object-glass of a telescope, and which was made to slide across the tube.

Vis Inertia.—Immobility without force; a power which, according to Newton, is implanted in all matter, of resisting any change from a state of rest.

Vitello.—A spot on the surface of the Moon called by that name.

Volume.—Dimensions; space occupied; bulk.

Volume of a Body.—The number of cubic units which it contains; or the number of times a solid contains another solid, taken as a unit of measure.

Vulpecula et Anser.—One of the northern constellations, the middle of which is R. A. 20*h.* 0*m.*, Dec. 23° N.

Wasat.—Another name for the star δ Geminorum, in the constellation Gemini.

Wave, Resultant.—That wave whose apex is at some intermediate place between the apexes formed by the action of the Sun and Moon, which depends upon the angular distances of those two luminaries.

Week.—A period of time, consisting of seven days, which dates its origin from the earliest antiquity, being used by the ancient Syrians, Egyptians, and most of the oriental nations.

Wega, or Vega.—A star of the first magnitude in the constellation Lyra, and known as α Lyræ.

Weight.—That property of bodies by which they tend to the centre of the Earth; gravity. The term weight is also used to express the relative value or importance of observations or determinations. Thus, an observation or measurement, whose weight on account of its accuracy is designated as *two,* is said to be equal to two observations or measurements the weight of each of which is only *one.* The rules of the weights of a series of observations are determined by multiplying each observation by its respective weight, adding the products, and dividing by the mean of the weights, instead of the arithmetical mean. *Gould.*

West.—One of the four cardinal points of the horizon, towards which the heavenly bodies set.

Wezen.—A star in the constellation Canis Major, called in the catalogues δ Canis Majoris.

Wire Micrometer.—A micrometer containing vertical and horizontal wires, much used in astronomical observations.

Wyes.—The supports of the telescope of the transit instrument, theodolite, &c.

Xiphias.—Another name for *Dorado,* which see.

Y's.—See WYES.

Year.—The time the Earth takes to perform her journey round the Sun.

Year, Anomalistic.—The time between two successive passages of the Earth through its aphelion or perihelion points.

Year, Bissextile.—See BISSEXTILE.

Year, Common.—That year which consists of 365 days, in contradistinction to the bissextile year, which consists of 366.

Year, Sidereal.—The time which the Sun takes in passing from any fixed star till he returns to it again is called a sidercal year.

Year, Tropical.—The time which the Sun takes in moving through the ecliptic from one tropic or equinox till it returns to it again is called a tropical or *solar year.*

Yed Posterior.—The name given to the eastern one of two stars called *Yed* in the constellation Ophiuchus, marked in the catalogues ε Ophiuchi.

Yed Prior.—A star in the constellation Ophiuchus, called also δ Ophiuchi.

Zaurak.—The name of a star in the constellation Eridanus; also known as γ Eridani.

Zavijava.—A star in the constellation Virgo, marked β Virginis in the catalogues.

Zenith.—The vertical point, or point in the heavens directly overhead.

Zenith, Apparent.—The point in which a plumb-line produced intersects the celestial sphere overhead.

Zenith, Central.—That point in which the radius of the Earth produced through the spectator's place intersects the celestial sphere.

Zenith Distance.—The distance of the Sun or a star from our zenith. The complement of the altitude, or what it wants of 90°.

Zodiac, (ζῶον, *an animal;* because the zodiacal constellations have the forms of animals given to them.)—A broad belt or zone in the heavens, within which all the orbits of the planets may be found except some of the asteroids. It extends to 8° on each side of the ecliptic.

Zodiacal Constellations.—Those twelve constellations through which the ecliptic passes, and through which the Sun appears to move. They are Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricornus, Aquarius, and Pisces.

Zodiacal Light.—A faint luminosity of a conical form which may sometimes be seen in the horizon after twilight.

Zodiacal Planets.—Those planets whose orbits lie within the limits of the zodiac.

Zodiacal Signs.—Certain astronomical characters which have been given to the zodiacal constellations. See CHARACTERS.

Zone.—A division of the Earth's surface by means of parallel circles. There are five zones: one torrid, two temperate, and two frigid. The father of the Greek philosopher, Thales, was the first person who divided the sphere into zones.

Zone of Declination.—A portion of the celestial sphere comprised between certain parallels of declination.

Zosma.—A star in the constellation Leo; also called δ Leonis.

Zuben-el-Akrab.—A star in the constellation Libra, called also η Libræ.

Zuben-el-Gemabi.—A star in the constellation Libra; also known as β Libræ. It is sometimes called *Kiffa Borealis* in catalogues.

Zuben-el-Gubi.—A small star in the constellation Libra; it is also known as γ Libræ.

Zuben-es-Chamali.—A star in Libra; also known as α Libræ, or *Kiffa Australis.*

TABLES.

TABLE I.

ELEMENTS OF THE PLANETARY SYSTEM.

	Inclination of Orbit to Ecliptic.	Inclination of Axis to Orbit.	Mass, Sun as Unity.	Density, Earth as Unity.	Time of Rotation on Axis.	Hourly Motion in Orbit in miles.	Mean Dist., Earth as Unity.
	° ′ ″	° ′ ″			d. h. m.		
Sun..........	....	7 30 00.0	1	0.25	25 7 48		
Mercury.....	7 0 9.1	unknown.	4865751	1.12	24 05	109,000	0.3870981
Venus........	3 23 28.5	73 32 00.0	401839	0.92	23 21	80,000	0.7233316
Earth.........	....	23 27 56.5	389551	1.00	24 00	68,000	1.0000000
*Mars........	1 51 06.2	30 18 10.8	2680337	0.95	24 37	55,000	1.5236923
Jupiter	1 18 51.3	3 05 30.0	1047.871	0.24	9 56	30,000	5.2027760
Saturn	2 29 35.7	31 19 00.0	3501.600	0.14	10 29	22,000	9.5387861
Uranus	0 46 28.4	0 00 00.0	24905	0.24	9 30?	15,000	19.1823900
Neptune.....	1 46 59.0	unknown.	18780	0.14	unknown.	10,000	30.0368000

	Sidereal Revolution in Solar Days.	Longitude of Perihelion.	Longitude of Ascending Node.	Eccentricity in parts of semi-axis.	True Diameter in miles.	Mean Apparent Diameter.
		° ′ ″	° ′ ″			′ ″
Sun	....	....	....	....	888,000	32 02.9
Mercury.........	87.9692580	74 21 46.9	45 57 30.9	0.2055149	3,140	00 06.9
Venus	224.7007869	128 43 53.1	74 54 12.9	0.0068607	7,800	00 16.9
Earth	365.2563612	99 30 5.0	....	0.0167836	7,916	
Mars	686.9796458	332 23 56.6	48 0 03.5	0.0933070	4,100	00 06.29
Jupiter	4332.5848212	11 08 34.6	98 26 18.9	0.0481621	88,000	00 36.74
Saturn	10759.2198174	89 09 29.8	111 56 37.4	0.0561505	79,160	00 16.20
Uranus	30686.8208296	167 31 16.1	72 59 35.3	0.0466794	34,500	00 04.0
Neptune	60126.7100000	47 12 56.7	130 8 11.0	0.0087195	41,500	00 02.5

* The table of Asteroids will be found in Table II.

TABLE II.—ELEMENTS OF THE ASTEROIDS.

No.	Name.	App. Mag.	Mean dist. from Sun, or semi-axis.	Mean Sid. period in mean Solar Days.	Angle of Eccentricity. ° ′ ″	Inclination of Orbit to Ecliptic. ° ′ ″	Longitude of Ascending Node. ° ′ ″	Longitude of Perihelion. ° ′ ″	Mean Daily Motion. ″	Epoch.*
1	Ceres	8	2.76805	1682.125	4 24 38.41	10 37 8.54	80 50 50.79	148 55 25.08	769.6387	1854, Jan., 0.0, W.
2	Pallas...........	7	2.77258	1686.510	13 49 26.1	34 42 1.4	172 37 11.7	121 47 16.2	768.6032	1855, Sept., 18.0, G.
3	Juno.............	8	2.67083	1594.296	14 51 19.4	13 3 31.9	170 57 37.1	54 13 3.9	814.2362	1855, May, 21.0, G.
4	Vesta............	6	2.36108	1325.147	5 7 42.9	7 8 19.3	103 23 44.4	251 11 21.7	977.2029	1855, Aug., 13.0, G.
5	Astrea...........	9	2.57704	1511.178	10 50 28.34	5 19 23.19	141 25 13.59	135 20 58.44	857.6089	1846, Jan., 0.0, B.
6	Hebe	9	2.42611	1380.184	11 39 15.8	14 46 32.1	138 31 55.3	15 15 25.7	939.3772	1852, July, 13.0, B.
7	Iris...............	8	2.38508	1345.403	13 22 57.06	5 28 12.32	259 45 58.31	41 15 49.31	962.4114	1854, June, 13.0, W.
8	Flora............	8	2.20168	1193.249	9 1 15.8	5 53 3.2	110 20 52.5	32 49 44.7	1086.0789	1852, Mar., 24.0, B.
9	Metis............	10	2.38689	1346.940	7 3 18.0	5 35 54.7	68 28 57.7	71 33 10.9	962.1801	1852, June, 4.0, B.
10	Hygeia..........	9	3.12089	2020.761	5 47 30.9	3 47 11.2	287 38 27.0	218 2 29.0	634.2404	1851, Sept., 28.5, P.
11	Parthenope	9	2.44652	1397.719	5 37 32.7	4 36 54.3	124 59 53.6	317 3 50.6	926.3256	1852, July, 13.0, B.
12	Clio..............	var.	2.33488	1303.148	12 37 16.3	8 23 12.5	235 30 7.5	301 53 33.3	994.6013	1852, Jan., 16.0, B.
13	Egeria...........	9	2.57836	1512.217	4 56 57.6	16 33 6.7	43 17 40.3	118 17 16.9	854.9641	1852, Mar., 15.0, B.
14	Irene	9	2.58490	1517.975	9 46 25.4	9 5 33.2	86 51 32.5	178 26 57.5	855.2336	1852, July, 13.0, B.
15	Eunomia........	9	2.64000	1566.768	10 52 7.0	11 43 39.9	293 53 56.2	27 34 16.7	823.3368	1852, July, 13.0, B.
16	Psyche..........	10	2.93295	1834.661	4 10 31.99	2 59 24.20	150 24 59.42	321 22 29.07	706.3977	1852, Mar., 17.0, G.
17	Thetis...........	10	2.47924	1425.857	7 31 10.52	5 35 39.31	125 26 25.15	259 13 17.99	908.9268	1852, June, 0.0, B.
18	Melpomene.....	9	2.29467	1269.633	12 30 49.8	10 9 9.3	149 59 34.4	15 14 38.2	1020.6810	1853, Jan., 0.0, W.
19	Fortuna.........	9	2.45854	1408.038	9 48 18.9	1 32 35.0	211 16 57.6	32 20 41.9	930.5316	1852, Sept., 27.35, B.
20	Massalia........	9	2.37585	1337.601	10 3 27.5	0 40 28.1	207 8 47.6	94 32 39.7	968.8970	1852, Nov., 0.0, B.
21	Lutelia..........	9	2.60477	1535.500	19 51 55.2	3 19 49.7	78 38 48.4	309 53 19.4	934.3241	1852, Dec., 0.0, B.
22	Calliope.........	9	2.91171	1814.763	6 0 11.8	14 20 12.6	66 53 6.1	46 13 28.9	703.4174	1852, Dec., 0.0. G.
23	Thalia...........	10	2.62642	1555.813	13 37 31.1	10 13 56.3	67 55 59.6	123 12 53.4	833.6046	1854, Jan., 0.0, W.
24	Themis..........	11	3.63940	2536.076	8 1 53.6	0 49 27.2	35 35 47.3	115 45 50.3	511.0350	1854, May, 2.44, B.
25	Phocea..........	9	2.37620	1358.619	14 23 41.7	21 43 3.9	214 6 0.1	302 41 17.7	952.9110	1854, May, 18.46, B.
26	Proserpine......	10	2.65241	1577.880	3 57 17.3	3 43 20.1	45 36 26.4	175 9 22.0	842.3476	1854, June, 0.0, B.
27	Euterpe.........	9	2.34785	1314.029	....	1 36 9.0	93 30 18.7	87 15 29.0	986.2801	1854, Jan., 1.037, B.
28	Bellona.........	10	2.78072	1693.692	9 53 4.50	9 25 6.8	144 57 56.3	117 23 5.6	765.1899	1854, Mar., 0.0, B.
29	Amphitrite.....	10	2.56373	1484.101	3 55 43.0	6 4 6.35	356 15 54.6	54 4 26.2	873.2580	1854, Mar., 0.0, B.
30	Urania..........	9	2.35833	1322.834	7 15 41.2	2 5 56.5	308 11 6.1	30 48 46.8	975.2079	1855, Jan., 1.0, B.
31	Euphrosyne ...	9	3.15800	2050.075	12 31 23.7	26 28 21.3	31 24 24.21	94 0 37.73	633.1689	1854, Sept., 14.0, B.
32	Pomona.........	10	2.58506	1518.109	....	5 39 2.9	220 44 20.5	195 46 56.0	853.6940	1854, Nov., 0.0, B.
33	Polymnia.......	9	2.37879	1339.902	12 58 2.1	1 22 20.6	1 12 29.2	22 25 58.4	967.2350	1854, Nov., 0.0, B.
34	Circe............	...	2.64977	1372.671	6 34 5.0	5 10 10.5	184 1 45.3	157 51 19.7	822.6160	1855, Apl., 20.45, B.
35	Leucothea......	...	2.96635	....	....	7 37 36	....	....	694.4790	1855, May, 0.0., B.

* The letters W, G, B, and P, in the last column, denote the Mean Time at Washington, Greenwich, Berlin, and Paris.

TABLE III.—Elements of the Moon.

Mean distance from the Earth, (in terrestrial radii)	59.96435
Mean sidereal revolution, (in mean solar days)	27.321661418
Mean synodical revolution, " " " "	29.530588715
Mean revolution of apogee, " " " "	3232.575343
Mean nodical revolution, " " " "	6793.39108
Mean longitude of node, (Epoch, Jan. 1, 1801)	13° 53′ 17″.7
Mean longitude of perigee, " " "	266° 10′ 7″.5
Mean longitude of Moon, " " "	118° 17′ 8″.3
Mean inclination of orbit	5° 8′ 47″.9
Inclination of axis to orbit	1° 32′ 9″
Eccentricity of orbit	0.0548442
Diameter in miles	2153
Apparent diameter at mean distance from the Earth	31′ 07″
Apparent diameter at least distance from the Earth	33′ 31″.07
Apparent diameter at greatest distance from the Earth	29′ 21″.91
Volume, (that of the Earth being 1)	0.0204
Mass, " " " "	0.011399
Density, " " " "	0.5657
Mean angular velocity per day	13.1764°

TABLE IV.—Altitude of the Principal Lunar Mountains, in English feet, calculated from the observations of Prof. Madler, by Hind.

Name of Mountain.	Altitude in feet.	Selenographic Position.	
		Longitude.	Latitude.
Newton	23,800	16° E.	77° S.
Curtius	22,200	3° W.	67° S.
Casatus	20,800	35° E.	74° S.
Posidonius	19,800	29° W.	31° N.
Short	18,700	10° E.	74° S.
Moretus	18,400	7° E.	70° S.
Calippus	18,300	10° W.	39° N.
Mutus	18,300	30° W.	63° S.
Huyghens	18,000	2° E.	20° N.
Clavius	18,000	15° E.	58° S.
Blancanus	18,000	21° E.	63° S.
Kircher	17,600	43° E.	67° S.
Hainzel	17,500	32° E.	41° S.
Catharina	17,400	23° W.	17° S.
Theophilus	17,300	26° W.	11° S.
Tycho, (W. border)	17,100	12° E.	43° S.
Picard	17,000	54° W.	14° N.
Pythagoras	16,900	60° E.	63° N.
Werner	16,600	3° W.	28° S.
Macrobius	16,200	45° W.	21° N.

TABLE V.—Diameters of some of the Principal Craters or Cavities on the Moon's surface, reduced from observations of Prof. Madler, by Hind.

Name.	Breadth in English miles.	Selenographic Position.	
		Longitude.	Latitude.
Bailly	149	65° E.	65° S.
Clavius	143	15° E.	58° S.
Schikard	127	55° E.	44° S.
Ptolemy	115	3° E.	9° S.
Schiller	113	38° E.	52° S.
Phocylides	96	56° E.	52° S.

TABLE VI.—Elements of Jupiter's Satellites.

No.	Sidereal Revolution.	Mean Distance. In radii of Jupiter.	Mean Distance. In miles.	Inclination of Orbit to a fixed plane proper to each.	Inclination of fixed plane to Jupiter's equator.	Retrograde rev. of nodes on fixed plane. Years.	Diameter. App., as seen from Jupiter.	Diameter. App., as seen from Earth.	Diameter. In miles.	Mass, that of Jupiter, 1.000,000,000.	Apparent diameter of Jupiter as seen from Satellites.
	d. h. m. s.			° ′ ″	° ′ ″		′ ″	″			° ′
1	1 18 27 33.506	6.04853	266,500	....	....	....	33 11	1.015	2440	17328	19 49
2	3 13 14 36.393	9.62347	423,400	0 27 50	0 1 5	29.9142	17 35	0.911	2190	23235	12 29
3	7 3 42 33.362	15.35024	675,400	0 12 20	0 5 2	141.7390	18 00	1.488	3580	88497	7 47
4	16 16 31 49.702	26.99835	1,187,900	0 14 58	0 24 4	531.0000	8 46	1.273	3060	42659	4 25

TABLE VII.—Elements of the Satellites of Saturn.

No.	Name.	Sidereal Revolution.	Mean Distance. In radii of Saturn.	Mean Distance. In Angular Measurement.	Mean Distance. In miles.	Epoch of Elements.	Mean Longitude at Epoch.	Longitude of Peri-Saturnium.	Eccentricity.
		d. h. m. s.		″			° ′ ″	° ′ ″	
1	Mimas............	0 22 37 22.9	3.1408	26.78	118,000	1789.7	264 16 36	104 42	0.06889
2	Enceladus........	1 8 53 6.7	4.0319	34.38	152,000	....	67 56 25	....	....
3	Tethys............	1 21 18 25.7	4.9926	42.57	188,000	1836.3	158 31 0	53 40 0	0.04217
4	Dione..............	2 17 41 8.9	6.399	54.54	240,000	1836.0	327 40 48	42 30 0	0.02
5	Rhea	4 12 25 10.8	8.932	76.16	336,000	1836.0	353 44 0	95 0 0	0.02269
6	Titan..............	15 22 41 25.2	20.706	176.55	778,000	1830.0	137 21 24	244 35 50	0.029223
7	Hyperion.........	21 4 20	25.029	213.3	940,000	1849.0	32?	295 0 0	0.115
8	Japetus...........	79 7 54 40.8	64.359	514.52	2,268,000	1790.0	269 37 48	....	....

TABLE VIII.—Dimensions of Saturn's Rings.

	Equatorial semi-diameters.	English miles.
Outer diameter of outer ring	4.4575	172,130
Inner diameter of outer ring	3.9232	151,500
Outer diameter of inner ring	3.8326	148,000
Inner diameter of inner ring	2.9648	114,480
Breadth of outer ring	0.26715	10,316
Breadth of inner ring	0.43391	16,755
Distance of inner ring (interior edge) from Saturn's limb	0.42838	18,628
The same, from Saturn's centre	1.48238	57,243

TABLE IX.—Elements of Satellites of Uranus.

No. of Sat.	Sidereal Revolution.	Mean Distance in miles.	Mean Apparent Distance.	Daily Motion.
	d. h. m. s.		″	″
1	2 12 29 20	119,994	13.54	142.8373
2	4 3 28 8	170,863	19.28	86.8732
3	10 23 2 47	278,627	31.44	41.35133
4	13 11 6 55.21	379,921	42.87	26.73943
5	38 1 48 0	796,372		
6	107 16 39 56	1,592,640		

TABLE X.—Elements of Satellite of Neptune.

Sidereal revolution	5d. 21h. 0m. 17s.
Apparent mean distance	16.75″.
Mean distance	232,000 miles.
Inclination of orbit	29°.

TABLE XI.

The following table shows the Right Ascension, Declination, and North Polar Distance, also the Principal Star, of each Constellation which will be on the Meridian, in any latitude, in the evening of each month in the year.

JANUARY.

Name.	Right Ascension.		Declination.	N. Polar Dist.	Principal Star.
	h. m.	° ′	° ′	° ′	
Reticulus	3 44	56 0	62 0 S.	152 0	
Eridanus	4 00	60 0	10 0 S.	100 0	Achernar.
Taurus	4 20	65 0	16 0 N.	74 0	Aldebaran.
Camelopardalus	4 30	67 30	70 0 N.	20 0	
Sceptrum Brandenburgium	4 30	67 30	15 0 S.	105 0	
Cela Sculptoria	4 44	71 0	40 0 S.	130 0	
Auriga	5 00	75 0	45 0 N.	45 0	Capella.
Dorado	5 00	75 0	62 0 S.	152 0	
Orion	5 20	80 0	0 0	90 0	Betelgeuse.
Lepus	5 20	80 0	18 0 S.	108 0	Arneb.
Mons Mensæ	5 20	80 0	75 0 S.	165 0	
Equuleus Pictorius	5 30	82 30	52 0 S.	172 0	
Columba	5 40	85 0	35 0 S.	125 0	Phaet.

FEBRUARY.

Canis Major	6 20	95 0	22 0 S.	112 0	Sirius.
Officina Typographia	6 43	100 45	17 0 S.	107 0	
Telescopium Herschelii	6 48	102 0	40 0 N.	50 0	
Argo Navis (*carina*)	7 0	105 0	52 0 S.	142 0	Canopus.
Gemini	7 20	110 0	25 0 N.	65 0	Castor.
Monoceros	7 20	110 0	0 0	90 0	
Canis Minor	7 22	110 30	7 0 N.	83 0	Procyon.
Lynx	7 24	111 0	50 0 N.	40 0	
Argo Navis	7 44	116 0	50 0 S.	140 0	

MARCH.

Pisces Volans	8 22	125 30	68 0 S.	158 0	
Cancer	8 24	126 0	20 0 N.	70 0	Acubens.
Pyxis Nautica	8 50	132 30	30 0 S.	120 0	
Felis	9 40	145 0	20 0 S.	110 0	

APRIL.

Sextans	10 0	150 0	0 0	90 0	
Antlia Pneumatica	10 0	150 0	35 0 S.	125 0	
Robur Caroli	10 8	152 0	60 0 S.	150 0	Miaplacidus.
Leo Minor	10 12	153 0	35 0 N.	55 0	
Leo	10 20	155 0	15 0 N.	75 0	Regulus.
Ursa Major	10 30	157 30	60 0 N.	30 0	Benetnasch.
Hydra	10 40	160 0	13 0 S.	103 0	Alphare.
Chameleon	11 0	165 0	78 0 S.	168 0	
Crater	11 8	167 0	15 0 S.	105 0	Alkes.

TABLE XI.—Continued.

MAY.

Name.	Right Ascension.				Declination.	N. Polar Dist.	Principal Star.
	h.	m.	°	'	° '	° '	
Crux	12	20	185	0	60 0 S.	150 0	Acrux.
Musca Australis	12	20	185	0	70 0 S.	160 0	
Corvus	12	21	185	4	20 0 S.	110 0	Algorab.
Coma Berenices	12	30	187	30	27 0 N.	63 0	
Cor Caroli	12	48	192	0	40 0 N.	50 0	Cor Caroli.
Canes Venatici	13	12	198	0	40 0 N.	50 0	
Virgo	13	14	198	8	5 0 N.	85 0	Spica.
Centaurus	13	20	200	0	50 0 S.	140 0	

JUNE.

Avis Solitarius	14	0	210	0	20 0 S.	110 0	
Bootes	14	28	217	0	30 0 N.	60 0	Arcturus.
Mons Menalus	14	40	220	0	15 0 N.	75 0	
Circinus	15	0	225	0	60 0 S.	150 0	
Libra	15	4	226	0	8 0 S.	98 0	Zubeneschamali.
Lupus	15	20	230	0	45 0 S.	135 0	
Corona Borealis	15	25	231	15	28 0 N.	62 0	Alphecca.
Quadrans Muralis	15	28	232	0	53 0 N.	37 0	
Ursa Minor	15	30	232	15	75 0 N.	15 0	Alrucabba.

JULY.

Triangulum Australis	16	0	240	0	65 0 S.	155 0	
Norma	16	8	242	0	50 0 S.	140 0	
Scorpio	16	19	244	45	26 0 S.	116 0	Antares.
Apus	16	44	251	0	73 0 S.	163 0	
Hercules	16	48	252	0	30 0 N.	60 0	Ras Algethi.
Serpens	17	0	255	0	3 0 N.	87 0	
Ara	17	0	255	0	55 0 S.	145 0	
Ophiuchus	17	8	257	0	0 0	90 0	Ras Alhague.

AUGUST.

Draco	18	0	270	0	65 0 N.	25 0	Thuban.
Cerberus	18	0	270	0	22 0 N.	68 0	
Taurus Poniatowski	18	20	275	0	7 0 N.	83 0	
Telescopium	18	20	275	0	52 0 S.	142 0	
Scutum Sobieski	18	32	278	0	10 0 S.	100 0	
Corona Australis	18	40	280	0	40 0 S.	130 0	
Lyra	18	44	281	0	38 0 N.	52 0	Wega.
Sagittarius	19	0	285	0	30 0 S.	120 0	Ruchbah.

SEPTEMBER.

Antinous	19	28	292	0	0 0	90 0	
Pavo	19	40	295	0	68 0 S.	158 0	
Aquila	19	40	295	0	10 0 N.	80 0	Altair.
Sagitta	19	48	297	0	18 0 N.	72 0	
Vulpecula	20	0	300	0	23 0 N.	67 0	
Cygnus	20	26	306	30	42 0 N.	48 0	Arided.
Delphinus	20	32	308	0	12 0 N.	78 0	
Capricornus	20	40	310	0	20 0 S.	110 0	Giedi.
Microscopium	20	40	310	0	38 0 S.	128 0	
Octans	21	0	315	0	85 0 S.	175 0	
Equuleus	21	4	316	0	5 0 N.	85 0	

TABLE XI.—Continued.

OCTOBER.

Name.	Right Ascension.		Declination.	N. Polar Dist.	Principal Star.
	h. m.	° ′	° ′	° ′	
Globus Æthereus	21 20	320 0	30 0 S.	120 0	
Indus	21 20	320 0	60 0 S.	150 0	
Cepheus	22 0	330 0	70 0 N.	20 0	Alderamin.
Grus	22 0	330 0	45 0 S.	135 0	
Aquarius	22 20	335 0	14 0 S.	104 0	
Pisces Australis	22 20	335 0	30 0 S.	120 0	Fomalhaut.
Lacerta	22 28	337 0	45 0 N.	45 0	
Gloria Fredericii	23 0	345 0	52 0 N.	38 0	
Pegasus	23 0	345 0	15 0 N.	75 0	Markab.

NOVEMBER.

Toucan	23 55	358 45	66 0 S.	156 0	
Pisces	0 20	5 0	10 0 N.	80 0	El Rischa.
Cassiopeia	0 40	10 0	60 0 N.	40 0	Schedir.
Phœnix	0 40	10 0	50 0 S.	140 0	
Andromeda	0 56	14 0	32 0 N.	58 0	Alpheratz.
Machina Electrica	1 24	21 0	30 0 S.	120 0	

DECEMBER.

Triangulum Minus	1 28	22 0	27 0 N.	63 0	
Cetus	1 40	25 0	12 0 S.	102 0	Menkar.
Triangulum	1 48	27 0	32 0 N.	58 0	
Hydrus	1 52	28 0	66 0 S.	156 0	
Aries	2 20	35 0	22 0 N.	68 0	Arietis.
Tarandus	2 32	38 0	80 0 N.	10 0	
Musca Borealis	2 40	40 0	28 0 N.	62 0	
Horologium	2 40	40 0	55 0 S.	145 0	
Caput Medusa	2 52	43 0	38 0 N.	52 0	
Fornax Chemica	3 0	45 0	30 0 S.	120 0	
Perseus	3 12	48 0	48 0 N.	42 0	Algenib.
Solarium	3 32	53 0	58 0 S.	148 0	

TABLE XII.

Containing the Magnitudes, Right Ascensions, and Declinations, of the Principal Stars.

Star's Name.	Common Name.	Mag.	Right Ascension.	Declination.
			h. m. s.	° ′ ″
β Cassiopeia	Caph	2	0 0 42	58 16 18 N.
α Andromeda	Alpheratz	2	0 0 53.9	28 17 23 N.
γ Pegasi	Algenib	3	0 5 46.3	14 22 38 N.
α Phenicis		3	0 18 1	43 12 20 S.
β Hydræ		3	0 18 3.6	78 4 18 S.
α Cassiopeia	Schedir	var.	0 32 18.3	55 44 29 N.
β Ceti	Diphda	2	0 36 18.4	18 47 0 S.
γ Cassiopeia		3	0 47 5	59 50 48 N.
β Andromeda	Merach	2	1 0 47	34 46 18 N.
α Ursæ Minoris	Polaris	2	1 6 30.3	88 32 11 N.
ε Eridani	Achernar	1	1 32 18.4	57 58 28 S.
β Arietis	Sheratan	3	1 45 49	20 1 24 N.
α Arietis	Arietis	2	1 59 0.4	22 46 28 N.
o Ceti	Mira	var.	2 11 16	3 42 18 S.
α Ceti	Menkar	2	2 54 42	3 31 4 N.
β Persei	Algol	var.	2 57 46	40 20 0 N.
α Persei	Mirphak	2	3 13 59.5	49 20 27 N.
η Tauri	Alcyone	3	3 38 52	23 39 11 N.
α Tauri	Aldebaran	1	4 27 36.2	16 12 49 N.
α Auriga	Capella	1	5 5 59	45 50 42 N.
β Orionis	Rigel	1	5 7 34.2	8 22 23 S.
β Tauri	El Nath	2	5 17 7.7	28 28 48 N.
γ Orionis	Bellatrix	2	5 16 33	6 12 0 N.
δ Orionis	Mintaka	2	5 24 36	0 24 38 S.
α Columbæ	Phad	2	5 34 24	34 9 13 S.
α Orionis	Betelgeuse	var.	5 47 19.3	7 22 33 N.
α Argus	Canopus	1	6 20 44	52 37 5 S.
α Canis Majoris	Sirius	1	6 38 46	16 31 15 S.
ε Canis Majoris	Adara	2	6 52 56	28 46 41 S.
δ Geminorum	Wasat	3	7 11 27.6	22 14 42 N.
α Geminorum	Castor	2	7 25 20.5	32 12 6 N.
α Canis Minoris	Procyon	1	7 31 42.5	5 35 36 N.
β Geminorum	Pollux	2	7 36 26.2	28 22 20 N.
δ Argus		2	8 40 7	54 5 43 S.
α Hydræ	Alphard	2	9 20 27.6	8 1 57 S.
α Leonis	Regulus	1	10 0 38.7	12 40 26 N.
γ Leonis	Algieba	2	10 11 8	20 39 0 N.
η Argus		2	10 39 26.7	58 55 21 S.
α Crateris	Alkes	3	10 52 0	17 26 54 S.
β Ursæ Majoris	Merak	2	10 52 8	57 14 18 N.
α Ursæ Majoris	Dubhe	2	10 54 44.6	62 31 57 N.
δ Leonis	Zosma	2	11 6 23.4	21 19 2 N.
β Leonis	Denebola	2	11 41 39.5	15 22 57 N.
β Virginis	Zavijava	3	11 42 22	2 40 0 N.
γ Ursæ Majoris	Phecda	3	11 46 11	54 30 3 N.
δ Ursæ Majoris	Megrez	3	12 7 28	57 55 18 N.
α Crucis	Acrux	1	12 18 33.8	62 17 39 S.
δ Corvi	Algorab	3	12 21 35	15 37 24 S.
β Corvi		2	12 26 46.5	22 35 40 S.
γ Virginis		4	12 33 33	0 34 18 S.
δ Virginis		3	12 47 33	4 16 6 N.
ε Virginis	Vindemiatrix	3	12 54 13	11 49 18 N.
α Virginis	Spica	1	13 17 33.4	10 24 11 S.
ζ Ursæ Majoris	Mizar	3	13 17 35.2	55 45 48 N.
η Ursæ Majoris	Benetnasch	2	13 41 49.3	50 2 18 N.
η Boötis	Muphrid	3	13 47 46.8	19 7 34 N.

TABLE XII.—CONTINUED.

Star's Name.	Common Name.	Mag.	Right Ascension.	Declination.
			h. m. s.	° ′ ″
β Centauri	Agena	1	13 53 37.9	59 40 14 S.
α Draconis	Thuban	3	14 0 3	65 8 24 N.
α Boötis	Arcturus	1	14 9 2.8	19 56 21 N.
α^2 Centauri	Bungula	1	14 29 47.8	60 13 53 S.
ϵ Boötis	Miræ	3	14 38 39.2	27 41 15 N.
α^2 Libræ		2	14 42 51.8	15 26 11 S.
β Ursæ Minoris	Kochab	2	14 51 10.7	74 44 53 N.
β Boötis	Nekkar	3	14 55 55	41 1 30 N.
β Libræ		2	15 9 12.4	8 50 41 S.
α Coronæ Borealis	Alphecca	2	15 28 32.9	27 12 19 N.
α Serpentis	Unuk-al-Hay	2	15 37 7.6	6 53 6 N.
β^1 Scorpii	Graffias	2	15 57 0.6	19 24 17 S.
α Scorpii	Antares	1	16 20 31.3	26 6 21 S.
α Herculis	Ras-Algethi	var.	17 8 2	14 34 30 N.
β Draconis	Ras-Alhague	3	17 27 9.4	52 24 37 N.
γ Draconis	Etamin	2	17 52 53	51 30 36 N.
α Lyræ	Wega	1	18 32 1.7	38 39 5 N.
β Lyræ	Sheliak	var.	18 44 43.5	33 11 49 N.
γ Lyræ	Sulaphat	3	18 52 57	32 28 30 N.
ζ Aquilæ	Deneb-el-Okáb	3	18 58 44.6	13 39 5 N.
δ Aquilæ		3	19 18 11.1	2 49 45 N.
β Cygni	Albireo	3	19 24 16	27 37 42 N.
γ Aquilæ	Tarazed	3	19 39 21.9	10 15 47 N.
α Aquilæ	Altair	1	19 43 42.4	8 29 19 N.
β Aquilæ	Alshain	4	19 48 11.2	6 2 52 N.
α Capricornii	Giedi	3	20 10 0.3	12 59 27 S.
β^2 Capricornii	Dabih	3	20 12 1	15 16 54 S.
α Pavonis		2	20 14 9.1	57 11 40 S.
α Delphini	Svalocin	3	20 32 12	15 21 6 N.
α Cygni	Arided	2	20 36 29.3	44 45 51 N.
61[1] Cygni		5	21 0 23.8	38 2 19 N.
ζ Cygni		3	21 6 45.9	29 38 3 N.
α Cephei	Alderamin	3	21 15 6.9	61 58 20 N.
β Aquarii		3	21 23 55.3	6 12 24 S.
β Cephei	Alphirk	3	21 26 46.3	69 55 29 N.
ϵ Pegasi	Enif	2	21 37 3.8	9 12 44 N.
α Aquarii	Sadalmelik	3	21 58 20	1 1 21 S.
α Grus		2	21 59 4.4	47 39 37 S.
ζ Pegasi		3	22 34 13.7	10 4 33 N.
α Pisces Australis	Fomalhaut	1	22 49 37.6	30 23 23 S.
β Pegasi	Scheat	2	22 56 1	27 13 0 N.
α Pegasi	Markab	2	22 57 32.4	14 25 34 N.
γ Cephei	Errai	3	23 33 35.9	76 49 24 N.

TABLE XIII.—Giving the Declination of the Sun for every day in the year.

Days of Month.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1	S. 23 3	S. 17 11	S. 7 41	N. 4 26	N. 14 59	N. 22 1	N. 23 9	N. 18 7	N. 8 24	S. 3 4	S. 14 21	S. 21 47
2	22 58	16 54	7 18	4 49	15 17	22 9	23 5	17 52	8 2	3 27	14 40	21 56
3	22 52	16 36	6 55	5 12	15 35	22 17	23 1	17 36	7 40	3 50	14 59	22 5
4	22 46	16 19	6 32	5 35	15 53	22 24	22 55	17 21	7 18	4 14	15 18	22 13
5	22 40	16 1	6 9	5 58	16 10	22 31	22 50	17 5	6 56	4 37	15 36	22 21
6	22 33	15 42	5 46	6 20	16 27	22 37	22 44	16 48	6 34	5 0	15 54	22 28
7	22 25	15 24	5 23	6 43	16 44	22 44	22 38	16 32	6 11	5 23	16 12	22 36
8	22 18	15 5	4 59	7 5	17 0	22 49	22 32	16 15	5 49	5 46	16 30	22 42
9	22 9	14 46	4 36	7 28	17 16	22 55	22 25	15 58	5 26	6 9	16 47	22 48
10	22 1	14 25	4 12	7 50	17 32	23 0	22 18	15 40	5 4	6 32	17 5	22 54
11	21 52	14 6	3 49	8 12	17 48	23 4	22 10	15 23	4 41	6 55	17 21	22 59
12	21 42	13 46	3 25	8 34	18 3	23 8	22 2	15 5	4 18	7 17	17 38	23 4
13	21 32	13 26	3 2	8 56	18 18	23 12	21 53	14 47	3 55	7 40	17 54	23 9
14	21 22	13 6	2 38	9 18	18 33	23 15	21 45	14 28	3 32	8 2	18 10	23 13
15	21 11	12 46	2 14	9 39	18 48	23 18	21 36	14 10	3 9	8 25	18 26	23 16
16	21 0	12 26	1 51	10 1	19 2	23 21	21 26	13 51	2 46	8 47	18 41	23 19
17	20 48	12 4	1 27	10 22	19 16	23 23	21 16	13 32	2 22	9 9	18 56	23 22
18	20 37	11 43	1 3	10 43	19 29	23 25	21 6	13 13	1 59	9 31	19 10	23 24
19	20 24	11 22	0 40	11 4	19 42	23 26	20 55	12 53	1 36	9 53	19 25	23 25
20	20 11	11 0	0 16	11 25	19 55	23 27	20 44	12 34	1 13	10 14	19 39	23 26
21	19 58	10 39	N. 0 8	11 45	20 7	23 28	20 33	12 14	0 49	10 36	19 52	23 27
22	19 45	10 17	0 32	12 6	20 20	23 28	20 21	11 54	0 26	10 57	20 5	23 28
23	19 31	9 55	0 55	12 26	20 31	23 27	20 9	11 34	0 2	11 18	20 18	23 27
24	19 17	9 33	1 19	12 46	20 43	23 26	19 57	11 13	S. 0 20	11 40	20 31	23 26
25	19 2	9 11	1 42	13 5	20 54	23 25	19 44	10 53	0 43	12 0	20 43	23 25
26	18 47	8 48	2 6	13 25	21 4	23 23	19 31	10 32	1 7	12 21	20 54	23 23
27	18 32	8 26	2 30	13 44	21 15	23 21	19 18	10 11	1 30	12 42	21 5	23 21
28	18 16	8 3	2 53	14 3	21 25	23 18	19 5	9 50	1 54	13 2	21 16	23 18
29	18 1	7 41	3 16	14 22	21 34	23 16	18 51	9 29	2 17	13 22	21 27	23 15
30	17 44		3 39	14 41	21 44	23 12	18 36	9 7	2 40	13 42	21 37	23 12
31	17 28		4 3		21 52		18 22	8 46		14 1		23 7

TABLE XIV.

The Principal Observatories in the World, with their Latitudes and Longitudes.

Name.	Latitude.	Longitude.
	° ′ ″	h. m. s.
Aberdeen	57 8 57.8 N.	0 8 22.78 W.
Abo	60 26 57 N.	1 29 8.8 E.
Altona	53 32 45.3 N.	0 39 46.6 E.
Armagh	54 21 12.7 N.	0 26 35.5 W.
Ashurst	51 15 58 N.	0 1 10.1 W.
Athens	37 58 20 N.	1 25 34.23 E.
Berlin	52 31 13.5 N.	0 53 35.5 E.
Berlin, (*New Observatory*)	52 30 16.7 N.	0 53 35.5 E.
Bilk	51 12 25 N.	0 27 4.93 E.
Birr Castle, (*Rosse*)	53 5 47 N.	0 31 40.9 W.
Bonn	50 44 9.1 N.	0 28 27 E.
Bremen	53 4 36 N.	0 35 15.9 E.
Breslau	51 6 56 N.	1 8 10 E.
Brussels	50 51 10.7 N.	0 17 29 E.
Buda	47 29 12.2 N.	1 16 12.7 E.
Cambridge, (United States)	42 22 49 N.	4 44 32 W.
Cambridge, (England)	52 12 51.8 N.	0 0 23.54 E.
Cape of Good Hope	33 56 3 S.	1 13 55 E.
Christiana	59 54 42.4 N.	0 42 53.9 E.
Cincinnati	39 5 54 N.	5 37 58.85 W.
Copenhagan	55 40 53 N.	0 50 19.8 E.
Cracow	50 3 50 N.	1 19 51.1 E.
Dantzic	54 21 18 N.	1 14 45 E.
Dorpat	58 22 47.1 N.	1 46 55 E.
Dublin	53 23 13 N.	0 25 22 W.
Durham	54 46 6.2 N.	0 6 18 W.
Edinburgh	55 57 23.2 N.	0 12 43.6 W.
Florence	43 46 41.4 N.	0 45 3.6 E.
Geneva	46 11 59.4 N.	0 24 37.7 E.
Georgetown	38 54 26.1 N.	5 14 32 W.
Göttingen	51 31 48 N.	0 39 46.5 E.
Gotha	50 56 5 N.	0 42 56.4 E.
Greenwich	51 28 38.2 N.	0 0 0
Hamburg	53 33 5 N.	0 39 54.1 E.
Hartwell	51 48 36 N.	0 3 24.33 W.
Hudson, (Ohio)	41 14 42.6 N.	5 25 41.3 W.
Kasan	55 47 23.1 N.	2 30 31.93 E.
Kensington	51 30 12.7 N.	0 0 46.78 W.
Königsberg	54 42 50 N.	1 22 0.5 E.
Kremsmünster	48 3 24 N.	0 56 32.3 E.
Leipsic	51 20 20.1 N.	0 49 28.5 E.
Leyden	52 9 28.2 N.	0 17 57.5 E.
Liverpool	53 24 47.8 N.	0 12 0.11 W.
London	51 31 29.9 N.	0 0 37.1 W.
Madras	13 4 9.2 N.	5 21 3.77 E.
Makerstown	55 34 45 N.	0 10 4 W.
Manheim	49 29 14 N.	0 33 51.4 E.
Markree	54 10 36 N.	0 33 48.4 W.
Marseilles	43 17 50.1 N.	0 21 29 E.
Milan	45 28 1 N.	0 36 47.2 E.
Modena	44 38 53 N.	0 43 43.2 E.
Moscow	55 45 19.8 N.	2 30 17 E.
Munich	48 8 45	0 46 26.5 E.
Naples	40 51 46.6 N.	0 57 0.3 E.
Nicolaeff	46 58 20.6 N.	2 7 55.1 E.
Oxford	51 45 36 N.	0 5 2.6 W.

TABLE XIV.—Continued.

Name.	Latitude.	Longitude.
	° ′ ″	h. m. s.
Padua	45 24 2 N.	0 47 29.2 E.
Palermo	38 6 44 N.	0 53 25.6 E.
Paramatta	33 48 49.8 S.	10 4 6.25 E.
Paris	48 50 13 N.	0 9 21.5 E.
Philadelphia	39 57 7.5 N.	5 0 38.36 W.
Portsmouth	50 48 3 N.	0 4 23.9 W.
Prague	50 5 18.5 N.	0 57 41.9 E.
Pulkova	59 46 18.6 N.	2 1 18.5 E.
Regent's Park, (London)	51 31 29.9 N.	0 0 37.1 W.
Rome	41 53 52 N.	0 49 54.7 E.
San Fernando	36 27 45 N.	0 24 49.1 W.
Santiago	32 26 24.8 S.	4 42 18.9 W.
Senftenberg	50 5 10 N.	1 5 50.5 E.
St. Helena	15 55 26 S.	0 22 50 W.
St. Petersburg	59 56 31 N.	2 1 15.8 E.
Speyer	49 18 55.2 N.	0 33 46.5 E.
Starfield	53 25 3.5 N.	0 11 47.34 W.
Stockholm	59 20 31 N.	1 12 14.8 E.
Strasburg	48 34 40 N.	0 31 0.8 E.
Turin	45 4 6 N.	0 30 48.4 E.
Upsala	59 51 50 N.	1 10 34.8 E.
Venice	45 25 49.5 N.	0 49 25.4 E.
Verona	45 26 0 N.	0 44 0.1 E.
Vienna	48 12 35.5 N.	1 5 31.9 E.
Viviers	44 29 11 N.	0 18 44.8 E.
Warsaw	52 13 5 N.	1 24 8.5 E.
Washington, (National Observatory)	38 53 38.6 N.	5 8 14 W.
Wateringbury	51 15 12 N.	0 1 39.8 E.
Wilna	54 41 0 N.	1 41 11.9 E.
Wrottesley Hall	52 37 2.3 N.	0 8 53.57 W.

Note.—The longitudes in the above table are reckoned from the meridian of Greenwich.

INDEX.

THE END.

STEREOTYPED BY L. JOHNSON AND CO.
PHILADELPHIA.